

Small Mammal Abundance Within Mexican Spotted Owl Home Ranges in the Manti-Lasal National Forest San Juan County, Utah

SMALL MAMMAL ABUNDANCE WITHIN MEXICAN SPOTTED OWL HOME RANGES IN THE MANTI-LASAL NATIONAL FOREST, SAN JUAN COUNTY, UTAH

FINAL REPORT

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Maite Sureda
School of Renewable Resources
University of Arizona
Biologica Science East, Room 104
Tucson, AZ 85721

PRINCIPAL INVESTIGATOR

Dr. Michael L. Morrison
School of Renewable Resources
University of Arizona
Biologica Science East, Room 325
Tucson, AZ 85721

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ABSTRACT

The Mexican spotted owl (Strix occidentalis lucida) was listed as a threatened subspecies in April 1993. Ecologists suspect that owls select specific areas based partially on the availability of prey. Mexican spotted owls in the Manti-LaSal National Forest in southeastern Utah spend > 75% of their time within the canyons and < 25% of their time on the mesas. My objective was to determine and compare the Mexican spotted owls primary prey species' distribution and abundance within the canyons and the mesas, and between the different vegetation types in each of the areas. I sampled within 7 vegetation types; 4 occurred within canyons, and 3 occurred on mesas. Four sampling areas were surveyed. Live-trapping was conducted during the summer and fall of 1994-95. Small mammal abundance was estimated as catch per unit effort which is equal to the number of new animals captured per 100 trap nights. Woodrat species (Neotoma spp.) are, in terms of percent biomass, the Mexican spotted owls primary prey species in this area, while Peromyscus spp. are important in terms of frequency. Woodrats were only captured in the canyons and were primarily captured within the pinyon-juniper vegetation type. The 3 Peromyscus species primarily consumed by the owls were also very abundant in the pinyon-juniper vegetation within the canyons. The Mexican spotted owls in the Manti-LaSal National Forest have been found to forage

within the pinyon-juniper vegetation type. My results suggest that pinyon-juniper vegetation stands within the canyons are an important component of the owls home range during the the summer and fall seasons in the Manti-LaSal National Forest.

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INTRODUCTION

The Mexican spotted owl (Strix occidentalis lucida) was listed as a threatened subspecies by the U.S. Fish and Wildlife Service in April 1993. Prior to its listing, involved State and Federal agencies classified the Mexican spotted owl as a sensitive subspecies due to its habitat needs, rarity, and need of special management considerations.

Most Mexican spotted owl literature focuses on habitat features necessary for only part of the owls direct needs, such as roosting, nesting, and perching trees or crevices within specific forest communities (Ganey 1994, Zwank et al. 1994). However, these components alone may not be enough to maintain the Mexican spotted owl in that particular area. There are numerous features that an animal may use in selecting areas in which they will reside. The factors involved in the decision-making process by an owl may include proximate factors such as the presence or absence of competitors or predators, temperature, food or mate availability, or factors that reflect geologic events and forces. All of these factors must be taken into consideration when evaluating the habitat needs of a species (Krebs 1985:58-67, Morrison et al. 1992:16-40).

Johnson (1980) depicted a hierarchical nature of habitat selection by a species or individual that consists of 4 orders. First-order selection describes the species'

geographical range. The Mexican spotted owl inhabits southern Utah and Colorado, Arizona, New Mexico, and west Texas into the mountains of central Mexico (Forsman et al. 1984, Ganey et al. 1988). Within Utah, Willey (1992) found the Mexican spotted owl to occur in Zion, Capitol Reef, and Canyonlands National Parks, and in the Manti-LaSal National Forest.

Within the geographic range is the home range of an animal, termed second-order selection (Johnson 1980). In southern Utah, the mean home range size of 11 individual owls in 3 study areas ranged from 924 to 1487 ha (2,282 to 3,672 acres; USDI Fish and Wildlife Service 1995:27).

Third-order selection defines the use of habitat components within the home range (Johnson 1980), such as foraging, nesting, and roosting sites. In the Manti-LaSal National Forest, Willey (1992) found that, in general, > 75% of owl telemetry locations occurred in steep canyons, while < 25% of the telemetry locations occurred on benches and mesa tops above the canyons. Willey (unpubl. data) also found that Mexican spotted owls in the Manti-LaSal National Forest are primarily foraging in the pinyon (*Pinus edulis*)-juniper (*Juniperus osteosperma*) vegetation community.

Finally, fourth-order selection is the use of specific items within the habitat components, such as food or nesting material. There are only a few studies that have examined

the food items consumed by the Mexican spotted owl in Utah. These studies have found that the primary prey species of the Mexican spotted owls, in terms of percent biomass, is woodrats (Neotoma spp.)(Kertell 1977, Wagner 1982, Ward and Block 1995). In these same studies, Peromyscus spp. were frequently found in Mexican spotted owl pellets. Similar results were observed in pellets collected from roost and nest sites of several pairs of owls in the Manti-LaSal National Forest (unpubl. data).

Ecologists suspect that spotted owls select habitats based partially on the availability of prey (Carey 1985, Ward and Block 1995). Thus, studies of prey species can provide insight into the ecology of a predator such as the spotted owl (Newton 1979, Carey 1985, Verner et al. 1992, Sakai and Noon 1993). For a pair of owls to nest successfully, the male must provide enough food for the female at the nest during the incubation and brooding period (Johnsgaard 1988). Thus, reproductive success is often correlated with prey abundance (Craighead and Craighead 1956, Southern 1970, Wendland 1984, Korpimäki and Norrdahl 1991).

Ward and Block (1995) proposed that an understanding of the ecology of primary prey species of the Mexican spotted owl is vital information needed for its recovery. This information can be another tool that managers can use for evaluating an area's ability to support and maintain spotted

owls. Yet, we know of no published studies that have examined abundances of primary prey species of Mexican spotted owls in Utah. Accordingly, this study was initiated to determine the distribution and relative abundance of the Mexican spotted owl's primary prey species in home ranges found within the Manti-LaSal National Forest in southeastern Utah. Because temporal variation occurs in habitat use by small mammals (Rosenzweig and Winakur 1969, Kelt et al. 1994), we examined relative abundances of prey items over 2 seasons within each of the 2 years of our study.

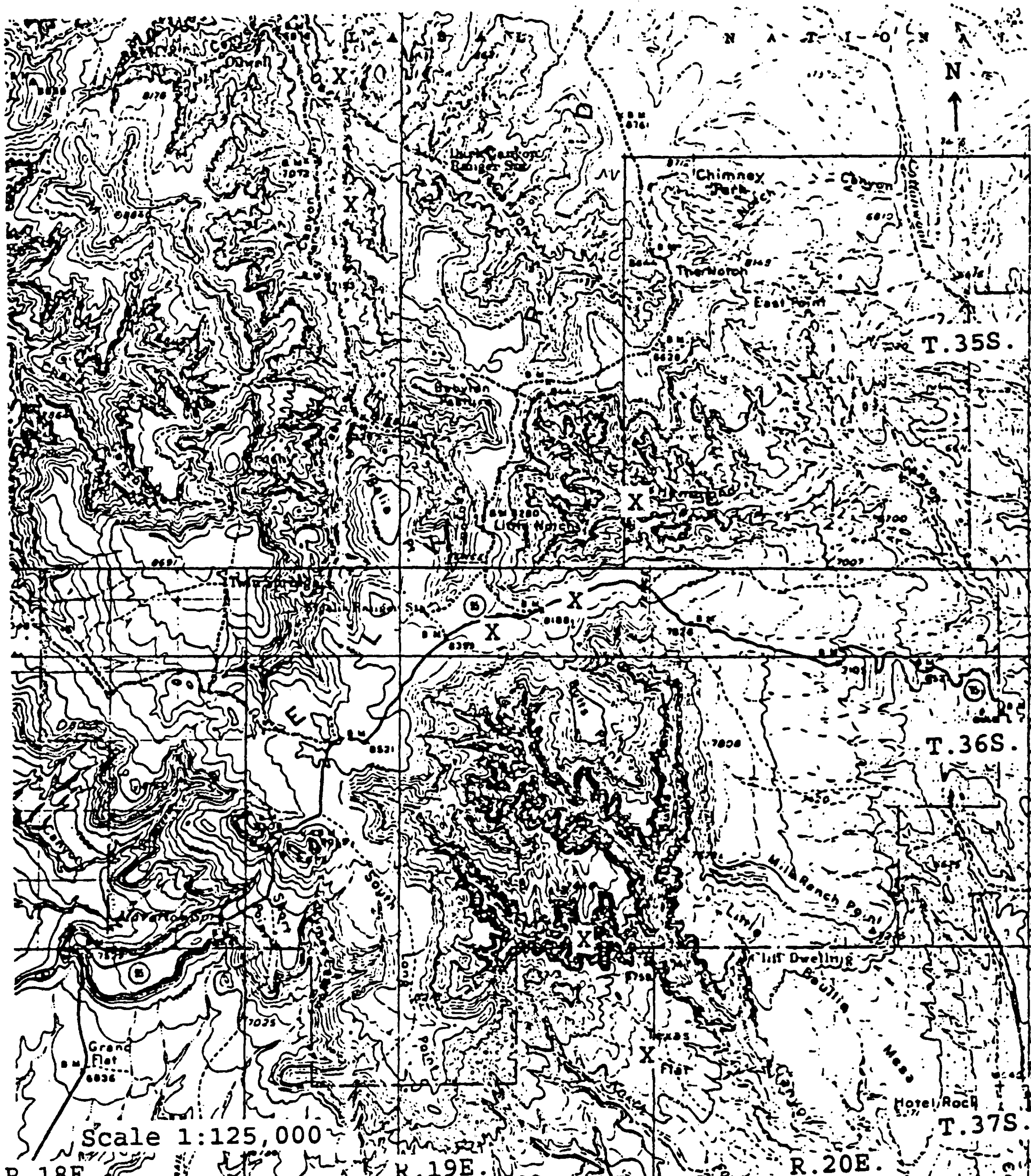
In consideration of second- and third-order habitat selection by Mexican spotted owls (home ranges and habitat components within homeranges, respectively; Johnson 1980), we surveyed in 4 Mexican spotted owl home ranges within the Manti-LaSal National Forest, and within these areas we focused the areas primarily used (canyons) and primarily not used (mesas) by the owls (macro-scale). Therefore, the primary objective of our study was to determine and compare the distribution and relative abundance of small mammals (specifically prey species of the Mexican spotted owl) within different vegetation types in the canyons and on the mesas of the Manti-LaSal National Forest. We tested the null hypothesis of no difference in small mammal relative abundances between the canyons and the mesas and between vegetation types.

A secondary objective of our study was to examine vegetation characteristics associated with the abundance and presence or absence of small mammals in this area. This objective focused on the micro-scale. The information obtained at this level may help to understand habitat use by small mammals in this area. From the literature, we recognized that each of the small mammal species captured may have specific vegetation characteristics associated with vegetation types. However, we hope to find commonalities between species at the micro-scale level so that managers can manage at the macro-scale; the vegetation types and/or canyons and mesas. The results of our study will be incorporated in the development of management plans for the conservation and recovery of the Mexican spotted owl in Utah.

STUDY AREA

Our study occurred on the Monticello Ranger District of the Manti-LaSal National Forest, San Juan County, Utah (Figure 1). The area is considered part of the Canyonlands Section of the Colorado Plateau geographic province (Thornbury 1965: 417,426). Elevation ranges from approximately 1,830 to 2,680 m. Elk Ridge, the dominant topographic feature of the study area, is flanked to the west and east by steep-walled canyons (Arch, Texas, Hammond, Peavine, and Dark canyons). Willey (unpubl. data) radio-tagged Mexican spotted owls in Texas, Hammond, Peavine, and

Figure 1. Map of the Monticello Ranger District showing study locations (X), Manti-LaSal National Forest, San Juan Co., Utah, 1995.



Dark canyons in 1992; in Texas and Hammond canyons in 1993; in Texas, Hammond, and Dark canyons in 1994; and in Texas canyon in 1995. Therefore, these 4 canyons were the areas of focus in my study. Peavine and Dark canyons were surveyed only in 1995, however, Texas and Hammond canyons were suveyed in both 1994 and 1995. The geography of our study area is of extensive sandstone canyonlands, stair-step benchlands, alluvial valleys, high plateaus, and laccolithic mountains (Barnes 1978). Vegetation is distributed in discrete layers, corresponding to exposed sandstone strata and elevation zones. The vegetation types occurring in the study area include sagebrush (Artemisia tridentata), pinyon-juniper woodlands, mixed-conifer (Pinus ponderosa, Abies concolor, Pseudotsuga menziesii), aspen (Populus tremuloides), riparian, and ponderosa pine (P. ponderosa).

Climate within our study area is characterized as semi-arid to arid with hot, dry summers (temperatures range from approximately 8° to 34° C in spring and summer; Bair 1992:985-988). Precipitation and snowfall occur mainly from October to May (temperatures range from approximately -4° to 16° C in fall and winter; average precipitation is approximately 30 cm; and average snowfall is approximately 2 m; Bair 1992:985-988).

METHODS

Grid Establishment

Within each Mexican spotted owl home range (n = 4), we set trapping grids within activity areas, as determined through owl telemetry locations in Texas, Hammond, Peavine, and Dark canyons. In the canyons, we set trapping grids within the following dominant vegetation types as defined by the Monticello Ranger District of the United States Forest Service: riparian, mixed-mountain brush, mixed-conifer, and pinyon-juniper (B. Thompson, U.S. Forest Service, person. commun.). We also set trapping grids on the mesas in the following dominant vegetative types: ponderosa pine forests [Vegetative Structural Stages (VSS) 3, 4, and 5]; grass-forb/shrub (VSS 1); and mixed aspen and ponderosa pine stands (VSS 2, 3, 4, and 5) (Reynolds et al. 1992).

In April 1994, we randomly established 20 trapping grids in Texas and Hammond canyons (8 in Texas, 12 in Hammond). During a trapping period 1 grid was sampled within each of the 4 canyon vegetation types mentioned. Therefore, there were 2 trapping periods in Texas Canyon and 3 in Hammond Canyon. On the mesas, we established 15 trapping grids, thus representing 5 trapping periods consisting of 1 trapping grid within each of the 3 mesa vegetation types mentioned.

In May 1995, additional grids (n = 6) were established in Peavine and Dark canyons. Dark Canyon grids represented mixed-conifer, pinyon-juniper, and grass-forb/shrub vegetation types. Peavine Canyon grids represented 3

variations of ponderosa pine vegetation types: ponderosa with shrub understory, ponderosa with rocky understory, and ponderosa with oak understory. Only 1 trapping period in each season was conducted for each of these canyons.

We randomly placed a grid within each vegetation type by standing on the edge of the vegetation type of interest and spinning a compass. The last digit of the compass reading was multiplied by 15 to determine the number of meters paced for grid placement. If the compass bearing was outside of the vegetation type being sampled, the bearing 180° from the first bearing was used.

We set the grids on the mesas in a 5 by 5 trapping station pattern. The canyon topography varied in width from approximately 100 m to 300 m; therefore, in order to fit a grid completely within some of the designated vegetation types, grids of various lengths and widths were used within the canyons. The mixed-conifer, mixed-mountain brush, and pinyon-juniper vegetation types were more block-like than was the riparian vegetation type. The grids in the "block-like" vegetation types were arranged in as close to a 5 by 5 pattern as possible (see Figure 2). The riparian vegetation type meandered through the canyon bottom; therefore, these grids were modified to fit the vegetation type and were irregular in shape (see Figure 3). All trapping stations were separated by 15 meters. A total of 41 grids were

trapped.

Trapping

Live-mammal trapping was conducted from May through October of 1994 and 1995. Each trapping period ran for 4 nights and 3 days. O'Farrell (1974) found that the moon had a negative effect on nocturnal rodent activity. Travers et al. (1988) also noted that nocturnal rodents were more active on dark than on bright nights, and also used protected rather than exposed microhabitats. Therefore, trapping was conducted only on nights around a new moon (10 nights before, 10 nights after).

At the beginning of the study (first 2 weeks), each trapping station consisted of two live traps: one large Sherman live-trap (7.6 X 8.2 X 22.9 cm), and either one extra-large Sherman live-trap (10 X 12 X 37 cm) or one Tomahawk live-trap (13 X 13 X 35 cm). Two trap sizes were used to increase the probability of catching woodrats and to minimize the potential bias against capturing the larger mammals in the smaller traps. However, due to logistical problems in transporting the Tomahawk traps within the canyons and the lack of woodrat captures in the Tomahawk traps, extra-large Sherman live traps were placed at every other trapping station and Tomahawk traps were no longer used. Therefore, for the remainder of the study, 13 trapping stations within each grid consisted of 1 extra-large Sherman

Figure 2. "Block-like" grid placement in a vegetation type within the canyons, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

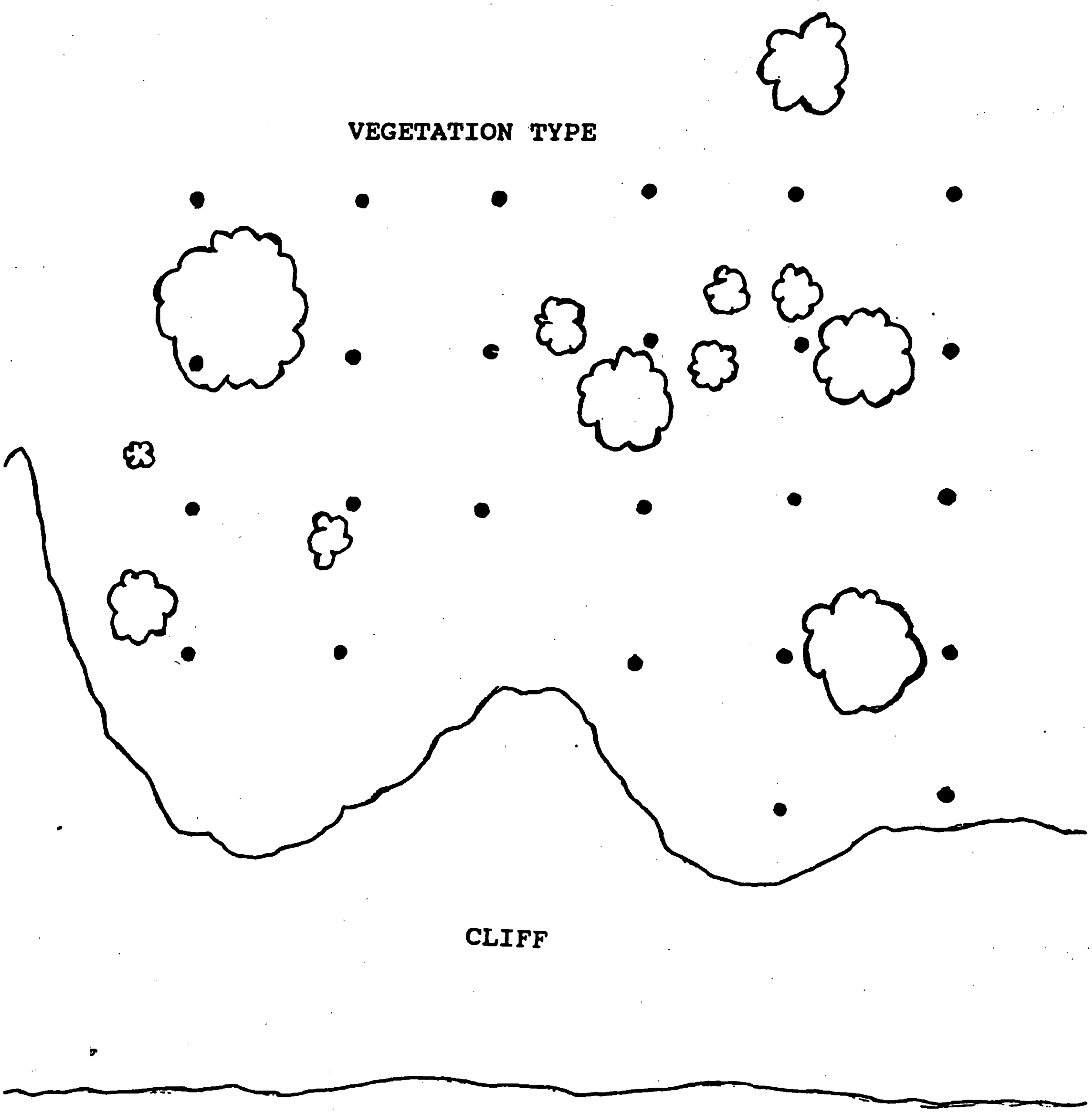
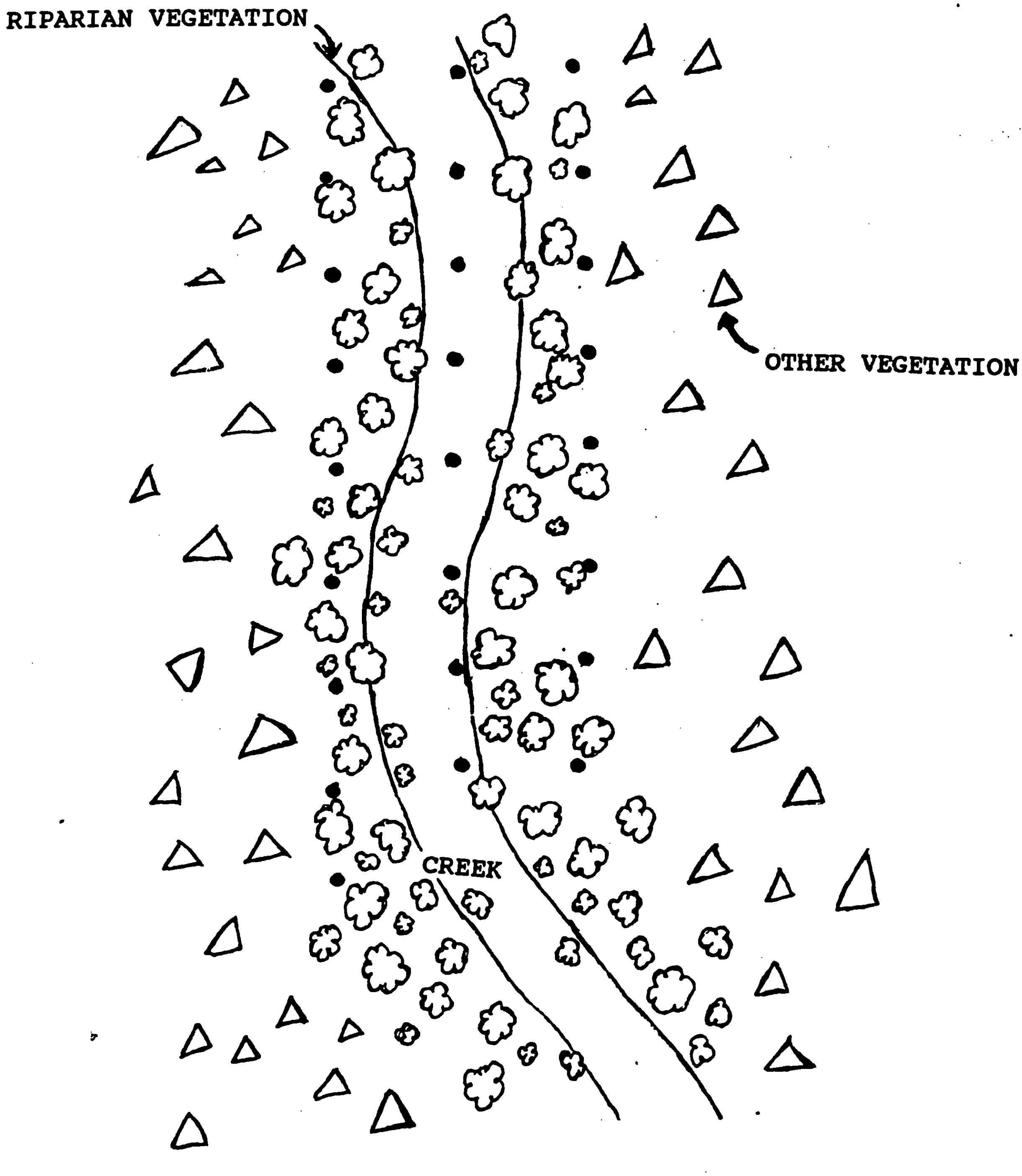


Figure 3. Grid placement in the riparian vegetation type within the canyons, Manti-LaSal National Forest, San Juan Co., Utah, 1995.



trap and 1 large Sherman trap, with the remaining 12 trapping stations consisting of 2 large Sherman traps.

All traps contained rolled oats, peanut butter, and batting (Davis 1982). The bait was placed in the middle of a clump of polyester batting at the back of each trap. This method was chosen in order to be consistent in presentation of bait and to provide insulation (Willy 1992).

All traps were set before sunset and checked at sunrise by either one or two technicians. Upon capture, all mammals were aged, sexed, weighed, and individually identified by toe-clipping. Age was differentiated between juvenile and adult. Reproductive condition was also recorded: non-reproductive, abdominal testes, or nipples.

Vegetation Sampling

We sampled vegetation at all trapping stations to determine microhabitat characteristics associated with small mammals captured. A circular plot with a 5-meter radius was centered on all trap stations. One 10-meter-diameter transect bisecting each plot was used to determine cover type, surface characteristics, canopy cover, and litter depth within each plot. The transect direction was determined by spinning a compass. Vegetation structure was estimated using a point intercept sampling method along the transects (Bonham 1989). All items (Appendix 1) and variables (Appendix 2) were recorded at every 1.0 meter mark.

Analysis

Only grids from Texas Canyon, Hammond Canyon, and 2 grids from Dark Canyon were used in the analyses that follow because they contained vegetation types that were similar to each other (pinyon-juniper, mixed-conifer, mixed-mountain brush, and riparian). The Peavine Canyon vegetation types and 1 Dark canyon vegetation type were not found in any other area and were thus excluded from small mammal-vegetation analyses.

Analyses of vegetation data were conducted using 8 species of small mammals that are known prey species of Mexican spotted owls in Utah and were found in the pellets collected and analyzed from the Manti-LaSal National Forest. The 8 species used were the deer mouse (<u>Peromyscus maniculatus</u>), canyon mouse (<u>P</u>. <u>crinitus</u>), brush mouse (<u>P</u>. <u>boylei</u>), pinyon mouse (<u>P</u>. <u>truei</u>), montane vole (<u>Microtus montanus</u>), Mexican woodrat (<u>Neotoma</u> <u>mexicana</u>), least chipmunk (<u>Tamias</u> <u>minimus</u>), and Colorado chipmunk (<u>T</u>. <u>quadrivittatus</u>). Ward and Block (1995) noted that the prey species predominantly found in Mexican spotted owl pellets in this area were the deer mouse, canyon mouse, brush mouse, and the Mexican woodrat. In addition to a small mammal's presence in owl pellets, all species were also considered for inclusion based on sample size (< 10 captures were excluded).

We estimated relative abundance of small mammals as

catch per unit effort (CE) which is the number of new or different animal captures per 100 trap-nights. Trap-nights is the number of traps per night times the number of nights in the field minus sprung-but-empty traps (Mills et al. 1991).

At the macro-scale, we compared relative abundance of small mammals in different vegetation types and between the canyons and the mesas using non-parametric tests. Non-parametric tests were used because the assumptions necessary for parametric tests could not be met for all species. Analyses were conducted on each species and on all species combined.

For comparisons between more than 2 groups, such as between vegetation types, the Kruskal-Wallis test for multiple comparisons (Zar 1984:201-202) was used. If a significant difference was found between the vegetation types, Dunn's test (Zar 1984:200) for multiple comparisons was used to determine where the difference occurred. The Mann-Whitney test (Zar 1984:138-146) was used to compare small mammal abundances between the canyons and the mesas.

In addition, the data were analyzed between seasons and years to determine if there were any statistical differences in relative abundance of small mammals in the different vegetation types between the summer and fall and between 1994 and 1995.

At the micro-scale, we conducted a series of analyses. The first analyses evaluated the relationship between small mammal numbers (relative abundance and presence) and vegetation variables over years and seasons to determine if data could be combined in further analyses. In consideration of relative abundances of small mammals, we conducted analyses over all vegetation types combined to get an overall understanding of what vegetation variables were associated with an increase in relative abundance of each small mammal over the entire study area. In consideration of the presence of each small mammal, we conducted analyses on each small mammal species using each trap station within each vegetation type to get more detatailed description of what vegetation variables are associated with the presence and/or absence of each small mammal species within each vegetation type.

At the micro-scale, we evaluated relationships between small mammal numbers (relative abundance or presence) and vegetation variables by seasons and years, using a multivariate analysis of variance (MANOVA; $\underline{P} = 0.05$; Zar 1984:244-251). A MANOVA was conducted to determine if data could be combined over seasons and years in subsequent analyses. These analyses differed from the non-parametric analyses above in that in the MANOVA analyses we were looking at the vegetation variables and how they were associated with each species in either all grids grouped or by vegetation

type (micro-scale). With the non-parametric tests we focused on the macro-scale only, considering species by vegetation type or canyons and mesas. One MANOVA analysis evaluated relative abundances of small mammals against vegetation variables on all grids combined. The other MANOVA analysis evaluated the presence of small mammals against vegetation variables at each trap station within a specific vegetation type.

Prior to conducting the MANOVA's, a correlation matrix (Sokal and Rohlf 1981:561-572) was produced using all vegetation variables, for each small mammal species, to determine if there was any high intercorrelation between the variables. If a pair of variables was highly intercorrelated (> 0.7), one of the variables was removed from the analysis. The variable used was the one with the most biological meaning and the one which was easiest to measure (Morrison et al. 1992:306).

To determine which vegetation variables might assist in describing a species' occurrence over the entire study area, a stepwise multiple regression (Zar 1984:328-30) was conducted on each species' relative abundance over all vegetation types combined. The variables used in the regression were the same ones used in the MANOVA analysis for each small mammal species. The criteria for entry (F-values) and exclusion of a variable into the regression were 0.10 and

0.11, respectively. The adjusted R^2 was used to evaluate the goodness of fit of the final model. An adjusted R^2 value is used to correct the optimistic bias associated with the relationship between R^2 and the number of explanatory variables included in the regression model (Dillon and Goldstein 1984:209-242). In addition, a power analysis (Zar 1984:312) was conducted to determine the probability of correctly rejecting any vegetation variables that did not account for the variation in small mammal abundance.

A normal probability plot and a scatterplot were used to check the residuals against the predicted values to test for normality and equal variances of the data which are assumptions needed to conduct parametric tests (Morrison et al. 1992:280-283). All of the 8 small mammal species considered for further analyses in regards to their relative abundances over all vegetation types combined had equal variances and were normally distributed. However, these assumptions were not met for all of the vegetation variables used in the MANOVA and multiple regression analyses. Therefore, stepwise multiple regression is used in a descriptive rather than predictive manner to help clarify habitat use by small mammals (Morrison et al. 1992:283-284).

To determine which vegetative variables might predict the presence or absence of a species within each vegetation type, a stepwise logistic regression (Hosmer and Lemeshow

1989:87-88) was conducted for each species in each of the 7 vegetation types. The criteria for inclusion of a variable into the logistic regression model was $\underline{P} = 0.10$, and $\underline{P} = 0.11$ was used for exclusion of the variable from the model. Assesment of how well the model fit the data was evaluated by using a classification table to compare the observed outcomes to the predicted outcomes. The Wald Chi-square (Hosmer and Lemeshow 1989:16-17), was used to evaluate the variables selected into the logistic regression model.

Due to highly unequal sample sizes in the number of each small mammal species present (or absent) compared to the number absent (or present) at each trap station within each vegetation type , 30 randomly selected subsamples of the largest sample (either presence or absence) were taken so that comparisons between presence and absence were equal. A stepwise logistic regression was conducted on each of the 30 subsamples. The vegetation variable(s) that occurred in >20% of the 30 models were force entered into a logistic regression model. The model with the final variables was the model used to describe the vegetation features associated with the presence or absence of a small mammal species in a particular vegetation type.

RESULTS

Frequencies

A total of 2,893 new or different animals were captured

in 25,148 trap nights. White-footed mice (deer mouse, canyon mouse, brush mouse, pinyon mouse) were by far the most captured species throughout the study (Table 1). Other species captured were 3 species of woodrats: Mexican woodrat, white-throated woodrat (N. albigula), and bushy-tailed woodrat (N. cinerea); 2 species of chipmunks: least chipmunk and Colorado chipmunk; rock squirrel (Spermophilus variegatus); silky pocket mouse (Perognathus flavus); montane vole; shrew sp. (Sorex spp.); western harvest mouse (Reithrodontomys megalotus); and Ord kangaroo rat (Dipodomys ordii; Table 1).

Peromyscus spp. were the most frequently captured animals in all but the aspen vegetation type in the fall of 1994 (Table 1). Neotoma spp. were only captured in the canyons and were, overall, most frequently captured in the pinyon-juniper vegetation type within the canyons (Table 1).

The vegetation type on the mesas that had the highest number of new animals overall was the grass-forb/shrub vegetation type (627), whereas in the canyons it was the pinyon-juniper vegetation type (462 new animals; Table 1). Similar results were also observed within each season, excluding the fall of 1994, where the mixed-mountain brush vegetation type and the riparian vegetation type in the canyons had a slightly higher number of new animals (157 and 143, respectively) than did the pinyon-juniper vegetation

Table 1. Percent frequency of captures of new or different small mammals by year, season, area, and vegetation type in the Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Year-Season Area Vegetation	n	No. new animals	*Peromyscus* spp.[a]	*Neotoma* spp.[b]	Other spp.[c]
1994-Summer					
Mesas	15	323	80.8		19.2
Aspen	5	77	80.5		19.5
Ponderosa	5	65	93.8		6.2
Shrub	5	181	76.2		23.8
Canyons	20	360	91.9	2.8	5.3
Mixed-conifer	5	70	94.3		5.8
Pinyon-juniper	5	115	86.1	7.0	7.0
Mixed-mtn.	5	96	91.7	2.1	6.3
Riparian	5	79	98.7		1.3
1994-Fall					
Mesas	15	249	71.9		28.1
Aspen	5	53	49.1		50.1
Ponderosa	5	35	71.4		28.6
Shrub	5	160	80.0		20.0

Table 1. Continued.

Canyons	20	532	91.0	5.8	3.2
Mixed-conifer	5	103	96.1	1.0	2.9
Pinyon-juniper	5	129	79.8	11.6	8.5
Mixed-mtn.	5	157	94.3	2.5	3.2
Riparian	5	143	89.5	6.3	4.2
1995-Summer					
Mesas	12	301	66.8		33.2
Aspen	4	93	54.8		45.2
Ponderosa	4	69	69.6		30.4
Shrub	4	139	73.4		26.6
Canyons	20	378	83.1	3.4	13.5
Mixed-conifer	5	78	78.2	2.6	19.2
Pinyon-juniper	5	107	85.0	4.7	10.3
Mixed-mtn.	3	65	81.5	4.6	13.9
Riparian	3	71	83.1	1.4	15.5
Shrub	1	25	92.0		8.0
Pond.-shrub	1	10	100.0		
Pond.-cliff	1	13	69.2	15.4	15.4
Pond.-oak	1	9	88.9		11.1
1995-Fall					
Mesas	9	328	72.9		27.1

Table 1. Continued.

Aspen	3	96	67.7		32.3
Ponderosa	3	85	68.2		31.8
Shrub	3	147	78.9		21.1
Canyons	18	422	77.5	1.4	19.4
Mixed-conifer	4	68	75.0		25.0
Pinyon-juniper	4	111	79.3	3.6	17.1
Mixed-mtn.	3	58	93.1		6.9
Riparian	3	54	79.6	1.9	18.5
Shrub	1	40	90.0		10.0
Pond.-shrub	1	34	64.7		35.3
Pond.-cliff	1	33	66.7	3.0	30.3
Pond.-oak	1	24	75.0		25.0
1994					
Mesas	30	572	76.9		23.1
Aspen	10	130	67.7		32.3
Ponderosa	10	100	86.0		14.0
Shrub	10	341	78.0		22.0
Canyons	40	892	91.4	4.6	4.0
Mixed-conifer	10	173	95.4	0.6	4.0
Pinyon-junip.	10	244	82.8	9.4	7.8
Mixed-mtn.	10	253	93.3	2.4	4.3

Table 1. Continued.

Riparian	10	222	92.8	4.1	3.1
1995					
Mesas	21	629	70.0		30.0
Aspen	7	189	61.4		38.6
Ponderosa	7	154	68.8		31.2
Shrub	7	286	76.2		23.8
Canyons	38	800	80.1	2.4	17.5
Mixed-conifer	9	146	83.6	1.4	15.0
Pinyon-juniper	9	218	82.1	4.1	13.8
Mixed-mtn.	6	123	87.0	2.4	10.6
Riparian	6	125	81.6	1.6	20.0
Shrub	2	65	90.8		9.2
Pond.-shrub	2	44	72.7		27.3
Pond.-cliff	2	46	67.4	6.5	26.1
Pond.-oak	2	33	78.8		21.2
Overall					
Mesas	51	1201	73.3		26.7
Aspen	17	319	63.9		36.1
Ponderosa	17	254	75.6		24.4
Shrub	17	627	77.2		22.8
Canyons	78	1692	86.1	3.5	10.4

Table 1. Continued.

Mixed-conifer	19	319	86.8	0.9	6.3
Pinyon-junip.	19	462	82.5	6.9	16.6
Mixed-mtn.	16	376	91.2	2.4	6.4
Riparian	16	347	88.8	3.2	8.0
Shrub	2	65	90.8		9.2
Pond.-shrub	2	44	72.7		27.3
Pond.-cliff	2	46	67.4	6.5	26.1
Pond.-oak	2	33	78.8		21.2
1994	70	1464	85.7	2.8	11.5
1995	59	1429	75.6	1.3	23.1
Overall	129	2893	80.7	2.1	17.2

[a]*Peromyscus maniculatus*, *P. crinitus*, *P. boylei*, and *P. truei*.

[b]*Neotoma mexicana*, *N. albigula*, *N. cinerea*.

[c]*Tamias minimus*, *T. quadrivittatus*, *Citellus variegatus*, *Perognathus flavus*, *Reithrodontomys megalotis*, *Dipodomys ordii*, *Sorex* spp., and *Microtus montanus*.

type (129; Table 1).

Relative Abundance - Mesas

Species.--The deer mouse was, overall, the most abundant species on the mesas and was found in all of the vegetation types (Appendix 3). Overall relative abundances ranged from 6.1 in the ponderosa pine vegetation type to 14.2 in the grass-forb/shrub vegetation type (Appendix 3). The brush mouse, canyon mouse, and pinyon mouse all had low overall relative abundances on the mesas ranging from 0.5 to 1.9 (Appendix 3). *Peromyscus* spp. were most abundant in the grass-forb/shrub vegetation type in 1994 and 1995 (5.6 and 7.7, respectively; Table 2).

Overall, the least chipmunk was most abundant in the grass-forb/shrub vegetation type with a relative abundance of 2.9 (Appendix 3). *Tamias* spp. were also most abundant in the grass-forb/shrub vegetation type in 1994 and 1995 (3.7 and 3.9, respectively; Table 2).

The montane vole was, overall, most abundant in the aspen vegetation type (Appendix 3). Montane voles and all other species were most abundant in the grass-forb/shrub vegetation type in 1994 and 1995 (1.7 and 2.4, respectively; Table 2).

Seasonal and Yearly Variation.--Relative abundance of grouped small mammal species did not differ significantly between seasons in either 1994 or 1995 ($P > 0.05$). Relative

abundance of grouped small mammal species during the summer did not differ between years, but relative abundance of grouped small mammal species was greater in the fall 1995 than fall 1994 (P = 0.0083, Kruskal-Wallis; Table 3).

Relative abundance of deer mice differed significantly between summer and fall of 1995 (P = 0.0329, Mann-Whitney) with the fall having the higher relative abundance. Significant differences in relative abundance of least chipmunks between 1994 and 1995 was observed (P = 0.0007, Mann-Whitney) with 1995 having the higher relative abundance. Relative abundance of montane voles differed significantly between the summers of 1994 and 1995 (P = 0.0251, Mann-Whitney) with the summer of 1995 having the higher relative abundance. Relative abundance of deer mice and least chipmunks differed significantly between the falls of 1994 and 1995 (P = 0.0170, P = 0.0065, respectively; Mann-Whitney) with the fall of 1995 having the higher relative abundance for both species.

Vegetation Types.--Comparisons of relative abundance of grouped small mammal species between the 3 mesa vegetation types differed significantly during the summer of 1994 (P = 0.0160, Kruskal-Wallis) and 1995 (P = 0364, Kruskal-Wallis) and the fall of 1994 (P = 0.0123, Kruskal-Wallis). Significant differences in grouped relative abundance of small mammal species was observed between the ponderosa pine

Table 2. Relative abundance[a] (± SD) of grouped small mammal species within each vegetation type on the mesas, 1994 and 1995, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Vegetation type / Species	1994 X (± SD)	1995 X (± SD)
Aspen		
Peromyscus spp.[b]	3.4(2.9)	6.0(4.8)
Neotoma spp.[c]	---	---
Tamias spp.[d]	2.2(0.5)	3.4(2.1)
Other spp.[e]	1.3(0.9)	1.7(1.0)
Ponderosa pine		
Peromyscus spp.[b]	3.3(2.8)	3.3(4.1)
Neotoma spp.[c]	---	---
Tamias spp.[d]	1.0(0.5)	3.4(1.4)
Other spp.[e]	---	0.7(0.2)
Grass-forb/shrub		
Peromyscus spp.[b]	5.6(7.0)	7.7(7.6)
Neotoma spp.[c]	---	---
Tamias spp.[d]	3.7(1.7)	3.9(1.3)
Other spp.[e]	1.7(1.5)	2.4(1.3)

[a] Relative abundance = No. of different animals captured per

Table 2. Continued.

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100 trap nights.

[b] Peromyscus maniculatus, P. crinitus, P. boylei, and P. truei.

[c] Neotoma mexicana, N. albigula, N. cinerea, and N. spp.

[d] Tamias minimus, T. quadrivittatus,

[e] Spermophilus variegatus, Perognathus flavus, Reithrodontomys megalotis, Dipodomys ordii, Sorex spp., and Microtus montanus.

Table 3. Mean relative abundance[a] (± SD) of grouped small mammal species by year, season, area and vegetation type, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Year-Season Area Vegetation	n	X	SD
1994-Summer			
Mesas	15	11.2	6.6
Aspen	5	7.9	6.4
Ponderosa pine	5	6.6	3.1
Grass-forb/shrub	5	19.1	6.1
Canyons	20	9.1	2.2
Mixed-conifer	5	7.1	1.5
Pinyon-juniper	5	11.9	5.5
Mixed-mountain brush	5	9.7	9.9
Riparian	5	7.8	4.0
1994-Fall			
Mesas	15	8.5	9.2
Aspen	5	5.5	7.8
Ponderosa pine	5	3.6	4.6
Grass-forb/shrub	5	16.3	9.1
Canyons	20	13.6	7.9

Table 3. Continued.

Mixed-conifer	5	10.4	5.4
Pinyon-juniper	5	13.9	10.3
Mixed-mountain brush	5	16.1	14.1
Riparian	5	14.1	7.9
1995-Summer			
Mesas	12	12.8	5.2
Aspen	4	11.9	1.4
Ponderosa pine	4	8.7	5.3
Grass-forb/shrub	4	17.7	3.7
Canyons	20	9.8	4.0
Mixed-conifer	5	8.1	4.0
Pinyon-juniper	5	11.2	2.2
Mixed-mountain brush	3	11.1	3.6
Riparian	3	12.3	5.9
Grass-forb/shrub	1	12.6	NA
Ponderosa-shrub	1	5.1	NA
Ponderosa-rock	1	6.7	NA
Ponderosa-oak	1	4.5	NA
1995-Fall			
Mesas	9	18.4	2.9
Aspen	3	16.1	2.4
Ponderosa pine	3	14.4	7.0

Table 3. Continued.

Grass-forb/shrub	3	24.9	8.0
Canyons	18	12.3	4.5
Mixed-conifer	4	8.6	5.3
Pinyon-juniper	4	14.4	4.0
Mixed-mountain brush	3	9.9	2.3
Riparian	3	9.2	2.4
Grass-forb/shrub	1	20.3	NA
Ponderosa-shrub	1	17.2	NA
Ponderosa-cliff	1	17.6	NA
Ponderosa-oak	1	12.0	NA
1994			
Mesas	30	9.9	7.5
Aspen	10	6.7	5.9
Ponderosa pine	10	5.1	3.5
Grass-forb/shrub	10	17.7	5.6
Canyons	40	11.4	5.2
Mixed-conifer	10	8.8	2.4
Pinyon-juniper	10	12.9	6.0
Mixed-mountain brush	10	12.9	4.7
Riparian	10	11.2	6.4
1995			
Mesas	21	15.2	6.7

Table 3. Continued.

Aspen	7	13.7	2.8
Ponderosa pine	7	11.1	6.3
Grass-forb/shrub	7	20.8	6.5
Canyons	38	10.8	4.4
Mixed-conifer	9	8.3	4.3
Pinyon-juniper	9	12.6	3.4
Mixed-mountain brush	6	10.5	2.8
Riparian	6	10.8	4.4
Grass-forb/shrub	2	16.5	5.4
Ponderosa-shrub	2	11.2	8.6
Ponderosa-rock	2	12.2	7.7
Ponderosa-oak	2	8.3	5.3
Overall			
Mesas	51	12.1	7.6
Aspen	17	9.6	5.9
Ponderosa pine	17	7.6	5.6
Grass-forb/shrub	17	19.0	6.0
Canyons	78	11.1	4.8
Mixed-conifer	19	8.5	3.3
Pinyon-juniper	19	12.7	4.8
Mixed-mountain brush	16	12.0	4.2
Riparian	16	11.0	5.5

Table 3. Continued.

Grass-forb/shrub	2	16.5	5.4
Ponderosa-shrub	2	11.2	8.6
Ponderosa-rock	2	12.2	7.7
Ponderosa-oak	2	8.3	5.3
1994	70	10.8	6.3
1995	59	12.4	5.7
Overall	129	11.5	6.1

[a] Relative abundance = No. of different animals captured per 100 trap nights.

vegetation type and the grass-forb/shrub vegetation type ($\underline{P} < 0.05$, Dunn's; for each of the seasons) with the grass-forb/shrub vegetation having a higher relative abundance than the ponderosa pine vegetation (Table 3). In the fall of 1995, there were significant differences in relative abundance of grouped small mammal species between the aspen-ponderosa pine and the grass-forb/shrub vegetation types ($\underline{P} < 0.001$, Dunn's), and between the ponderosa pine and grass-forb/shrub vegetation types ($\underline{P} < 0.001$, Dunn's) with the grass-forb/shrub vegetation having a higher relative abundance in both cases (Table 3). Overall, and within each year, the vegetation type on the mesas with the highest relative abundance of grouped small mammal species was the grass-forb/shrub vegetation type (19.0; Table 3).

Significant differences in relative abundance between the mesa vegetation types was observed with the deer mouse in the summer of 1994 ($\underline{P} = 0.0176$, Kruskal-Wallis), and with the montane vole in the fall of 1994 ($\underline{P} = 0.0319$, Kruskal-Wallis).

Relative Abundance - Canyons

<u>Species</u>.--The deer mouse was the most abundant species in the canyons and was found in all vegetation types (Appendix 3). Overall, relative abundance of deer mice ranged from 4.6 in the pinyon-juniper vegetation type to 15.0 in the grass-forb/shrub vegetation type in Peavine canyon

(Appendix 3). In the canyons, overall relative abundance of pinyon mice ranged from 0.5 to 1.7, of canyon mice from 4.7 to 3.1, and of brush mice from 0.5 to 3.4 (Appendix 3). Peromyscus spp. were the most abundant species' captured in all canyon vegetation types (Table 4).

The Mexican woodrat, white-throated woodrat, and the bushy-tailed woodrat had low overall relative abundances in the canyons ranging from 0.5 to 1.4 (Appendix 3). Neotoma spp. were most abundant in the pinyon-juniper vegetation type in 1994 and 1995 (Table 4). Overall, the Mexican woodrat was most abundant in the pinyon-juniper vegetation type (1.4) followed by the mixed-mountain vegetation type (0.8; Appendix 3).

Overall, the relative abundance of least chipmunks was 1.8, and relative abundance of Colorado chipmunks was 1.6 (Appendix 3). The least chipmunk was most abundant in the ponderosa with shrub understory vegetation type in Peavine canyon in the fall of 1995 (6.1; Appendix 3), while the Colorado chipmunk was most abundant in the pinyon-juniper vegetation type in the summer of 1995 (3.1; Appendix 3). Tamias spp. were most abundant in the pinyon-juniper vegetation type in 1994 and in the riparian vegetation type in 1995 (1.5 and 2.0, respectively; Table 4).

The montane vole and the rock squirrel were, overall, most abundant in the riparian vegetation type with relative

abundances of 0.7 and 1.0, respectively (Appendix 3). These species, as well as all of the other species not mentioned above, were most abundant in the riparian vegetation type in 1994 and 1995 (0.7 and 0.8, respectively; Table 4).

Seasonal and yearly variation.--In 1994, there was a significant difference in relative abundance of grouped small mammal species between summer and fall (P = 0.0003, Mann-Whitney) with the fall having the higher relative abundance (Table 3). No significant difference in relative abundance of grouped small mammals species was observed between seasons in 1995 (P < 0.05). Comparisons of relative abundance of grouped small mammal species for each season between years were not significantly different (P > 0.05).

Relative abundance of brush mice and Mexican woodrats differed significantly between seasons in 1994 (P = 0.0001 and P = 0.0013, respectively; Mann-Whitney) with the fall having the higher relative abundance for the brush mouse, and the summer having the higher relative abundance for the Mexican woodrat (Appendix 3). Relative abundance of the canyon mouse differed significantly between the seasons in 1995 (P = 0.0250, Mann-Whitney) with the summer having the higher relative abundance (Appendix 3). Relative abundance of brush mice and least chipmunks differed significantly between years (P < 0.0000 and P = 0.0006, respectively; Mann-Whitney) with 1995 having the higher relative abundance of

Table 4. Relative abundance[a] (± SD) of grouped small mammal species within each vegetation type in the canyons, 1994 and 1995, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Vegetation type Species	1994 X (± SD)	1995 X (± SD)
Mixed-conifer		
Peromyscus spp.[b]	3.8(2.6)	3.3(1.7)
Neotoma spp.[c]	0.5(0)	0.5(0)
Tamias spp.[d]	0.9(0.1)	1.6(0.8)
Other spp.[e]	0.5(0)	0.5(0)
Pinyon-juniper		
Peromyscus spp.[b]	3.1(1.9)	3.7(1.6)
Neotoma spp.[c]	1.0(0.8)	0.7(0.2)
Tamias spp.[d]	1.5(1.0)	1.9(1.1)
Other spp.[e]	0.5(0)	0.5(0)
Mixed-mountain brush		
Peromyscus spp.[b]	3.5(3.3)	4.5(1.9)
Neotoma spp.[c]	0.9(0.2)	0.8(0)
Tamias spp.[d]	1.1(1.0)	0.9(0.8)
Other spp.[e]	0.5(0)	0.7(0.3)
Riparian		
Peromyscus spp.[b]	3.5(3.3)	4.0(1.0)

Table 4. Continued.

Neotoma spp.[c]	0.8(0.4)	0.5(0)
Tamias spp.[d]	0.8(0.4)	2.0(1.5)
Other spp.[e]	0.7(0.2)	0.8(0.4)

[a] Relative abundance = No. of different animals captured per 100 trap nights.

[b] Peromyscus maniculatus, P. crinitus, P. boylei, and P. truei.

[c] Neotoma mexicana, N. albigula, N. cinerea, and N. spp.

[d] Tamias minimus, T. quadrivittatus,

[e] Spermophilus variegatus, Perognathus flavus, Reithrodontomys megalotis, Dipodomys ordii, Sorex spp., and Microtus montanus.

both species (Appendix 3). Significant differences in relative abundance of deer mice, Mexican woodrats, and least chipmunks were observed between the summers of 1994 and 1995 ($\underline{P}$ = 0.0430, $\underline{P}$ = 0.0418, and 0.0092, respectively; Mann-Whitney) with the summer of 1994 having the higher relative abundance for the Mexican woodrat and the least chipmunk, and the summer of 1995 being higher for the deer mouse (Appendix 3). Relative abundance of canyon mice, Mexican woodrats, and least chipmunks differed significantly between the falls of 1994 and 1995 ($\underline{P}$ = 0.0001, $\underline{P}$ = 0.0046, and $\underline{P}$ = 0.0092, respectively; Mann-Whitney) with the fall of 1994 having the higher relative abundance of canyon mice and Mexican woodrats, and the fall of 1995 having the higher relative abundance of least chipmunks (Appendix 3).

Vegetation type.--In 1994, both the pinyon-juniper and mixed-mountain brush vegetation types equally had the highest relative abundance of grouped small mammal species in the canyons (12.9; Table 3). In 1995, the shrub vegetation type in Peavine canyon had the highest relative abundance of grouped small mammal species (16.5) followed by the pinyon-juniper vegetation type with 12.6 (Table 3). The pinyon-juniper vegetation type had the highest overall relative abundance of grouped small mammal species (12.7; Table 3). However, relative abundances of grouped small mammal species did not differ significantly between the canyon vegetation

types for any of the seasons or years ($\underline{P}$ = 0.1786, summer 1994; $\underline{P}$ = 0.0760, fall 1994; $\underline{P}$ = 0.2254, summer 1995; $\underline{P}$ = 0.2296, fall 1995; Kruskal-Wallis).

Significant differences in relative abundance between the canyon vegetation types were observed with the brush mouse and the pinyon mouse in the fall of 1994 ($\underline{P}$ = 0.0219 and $\underline{P}$ = 0.0054; Kruskal-Wallis), and also with the pinyon mouse in the summer of 1995 ($\underline{P}$ = 0.0133, Kruskal-Wallis).

Relative Abundances - Canyons versus Mesas

During the summer of 1994 and 1995, relative abundance of grouped small mammal species in the canyons was not significantly different from relative abundance of grouped small mammal species on the mesas ($\underline{P}$ = 0.8113 and $\underline{P}$ = 0.0833, respectively; Kruskal-Wallis). In the fall of 1994 and 1995, relative abundance of grouped small mammal species was significantly different between the canyons and mesas ($\underline{P}$ < 0.0001 and $\underline{P}$ = 0.0268, respectively; Kruskal-Wallis). During the fall of 1994, relative abundance of grouped small mammal species was higher in the canyons than on the mesas (13.6 to 8.5, respectively; Table 3). In the fall of 1995, the reverse was observed with the mesas having a higher relative abundance of grouped small mammal species than the canyons (18.4 to 12.3, respectively; Table 3). However, overall (years and seasons combined), there was no significant difference in relative abundance of grouped small mammal

species between the canyons and mesas ($\underline{P}$ = 0.5913; Mann-Whitney).

Significant differences in relative abundance between the canyons and mesas was observed with the following small mammal species. The deer mouse had a significantly higher relative abundance on the mesas during fall 1995 ($\underline{P}$ = 0.0002, Mann-Whitney; Appendix 3). The canyon mouse had a significantly higher relative abundance in the canyons during summer 1994 ($\underline{P}$ = 0.0002, Mann-Whitney), summer 1995 ($\underline{P}$ = 0.0370, Mann-Whitney), and fall 1994 ($\underline{P}$ < 0.0000, Mann-Whitney; Appendix 3). The brush mouse had a significantly higher relative abundance in the canyons during fall 1994 ($\underline{P}$ = 0.0002, Mann-Whitney), and fall 1995 ($\underline{P}$ = 0.0021, Mann-Whitney), while in summer 1995, relative abundance was significantly higher on the mesas ($\underline{P}$ = 0.0014, Mann-Whitney; Appendix 3). The pinyon mouse had a significantly higher relative abundance in the canyons during fall 1994 ($\underline{P}$ = 0.0122, Mann-Whitney; Appendix 3). The Mexican woodrat had a significantly higher relative abundance in canyons during fall 1994 ($\underline{P}$ = 0.0002, Mann-Whitney) and summer 1995 ($\underline{P}$ = 0.01, Mann-Whitney; Appendix 3). The least chipmunk had a significantly higher relative abundance on the mesas during summer 1994 ($\underline{P}$ = 0.0017, Mann-Whitney) and 1995 ($\underline{P}$ = 0.0014, Mann-Whitney; Appendix 3). The Colorado chipmunk had a significantly higher relative abundance in the canyons during

summer 1994 (P = 0.0399, Mann-Whitney) and 1995 (P = 0.0370, Mann-Whitney), and fall 1995 (P = 0.0271, Mann-Whitney; Appendix 3). The montane vole had a significantly higher relative abundance on the mesas during summer 1994 (P = 0.0061, Mann-Whitney) and 1995 (P = 0.0006, Mann-Whitney), and fall 1994 (P = 0.0132, Mann-Whitney; Appendix 3).

Manova results

Manova results regarding the relative abundance of each small mammal species over all vegetation types combined showed that no interaction occurred between seasons and years or in season and year main effects for 7 of the 8 small mammal species used in the analyses (Table 5). Therefore, data for the 7 species without interaction were grouped over seasons and years for the multiple regression analyses. The canyon mouse did have interaction between seasons and years (Table 5); however, due to the small sample size captured in 1995 in both seasons, multiple regression analyses were conducted only on data for the summer and fall of 1994.

MANOVA results regarding the presence or absence of each small mammal species within each vegetation type indicated that 91.4% of the 8 species used in these analyses did not have interactions between years and/or seasons (Table 6). Interaction between years and seasons was observed with the Colorado chipmunk in the mixed-conifer vegetation type (P = 0.000) and with the brush mouse in the mixed-mountain brush

Table 5. MANOVA results (*P* values) of relative abundance of each small mammal species over all vegetation types combined to determine if interaction between years and seasons was observed, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Species	Year	Season	Year by Season
Peromyscus maniculatus	0.890	1.000	1.000
P. crinitus	0.017	0.006	0.015
P. boylei	0.128	0.497	0.391
P. truei	0.317	0.795	0.904
Neotoma mexicana	0.993	0.988	0.990
Microtus montanus	0.802	0.866	0.970
Tamias minimus	0.750	1.000	0.983
T. quadrivittatus	0.960	0.922	0.922

Table 6. MANOVA results (P values) of presence or absence of each small mammal species within each vegetation type to determine if interaction between years and seasons was observed, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Vegetation Type Species	Year	Season	Year by Season
Ponderosa pine			
Peromyscus maniculatus	0.521	0.964	0.506
P. crinitus	---	---	---
P. boylei	---	---	---
P. truei	---	---	---
Neotoma mexicana	---	---	---
Microtus montanus	---	0.669	---
Tamius minimus	0.746	0.312	0.880
T. quadrivittatus	---	---	---
Aspen			
Peromyscus maniculatus	0.589	0.635	0.472
P. crinitus	---	---	---
P. boylei	---	---	---
P. truei	---	---	---
Neotoma mexicana	---	---	---

Table 6. Continued.

Microtus montanus	0.839	0.343	0.581
Tamius minimus	0.285	0.498	0.079
T. quadrivittatus	---	---	---
Grass-forb/shrub			
Peromyscus maniculatus	0.769	0.128	0.685
P. crinitus	---	---	---
P. boylei	0.962	0.849	0.641
P. truei	---	---	---
Neotoma mexicana	---	---	---
Microtus montanus	0.505	0.713	0.558
Tamius minimus	0.532	0.518	0.365
T. quadrivittatus	---	---	---
Pinyon-juniper			
Peromyscus maniculatus	0.176	0.485	0.976
P. crinitus	0.092	0.269	---
P. boylei	0.842	0.977	0.930
P. truei	0.413	0.548	0.929
Neotoma mexicana	0.829	0.951	0.829
Microtus montanus	---	---	---
Tamius minimus	0.570	0.708	---
T. quadrivittatus	0.333	0.322	0.942
Mixed-conifer			
Peromyscus maniculatus	0.015	0.690	0.427

Table 6. Continued.

P. crinitus	0.871	0.373	---
P. boylei	0.175	0.538	---
P. truei	0.123	---	---
Neotoma mexicana	---	---	---
Microtus montanus	---	---	---
Tamius minimus	0.236	0.806	0.934
T. quadrivittatus	0.001	0.003	0.000
Mixed-mountain brush			
Peromyscus maniculatus	0.530	0.669	0.949
P. crinitus	0.929	0.300	---
P. boylei	0.012	0.051	0.035
P. truei	---	---	---
Neotoma mexicana	0.920	0.920	---
Microtus montanus	---	---	---
Tamius minimus	0.137	0.635	0.626
T. quadrivittatus	0.810	0.950	0.893
Riparian			
Peromyscus maniculatus	0.873	0.955	0.944
P. crinitus	0.205	0.658	---
P. boylei	0.834	0.960	---
P. truei	---	---	---
Neotoma mexicana	0.930	0.217	---
Microtus montanus	---	---	---

Table 6. Continued.

Tamius minimus	0.897	0.949	0.766
T. quadrivittatus	0.829	0.953	0.843

vegetation type ($\underline{P}$ = 0.035). Differences between years were observed with the deer mouse in the mixed-conifer vegetation type ($\underline{P}$ = 0.015), with the brush mouse in the mixed-mountain brush vegetation type ($\underline{P}$ = 0.012), and with the Colorado chipmunk in the mixed-conifer vegetation type ($\underline{P}$ = 0.001). Differences between seasons were observed only with the Colorado chipmunk in the mixed-conifer vegetation type ($\underline{P}$ = 0.036). If sample size was small (≤5 cases for a species) it was excluded from the analysis for that particular vegetation type. Because only 8.6% of the small mammal species had interaction of some kind between years and/or seasons in each of the vegetation types, all species were used in stepwise logistic regression on each species for each vegetation type on combined years and seasons.

Multiple Regression

The significance level criteria for stepwise multiple regression, based on the relative abundance of each small mammal species with all vegetation types combined, was reached by the inclusion of ≤4 variables in each model (Table 7). The adjusted $\underline{R}^2$ value ranged from 0.03 for the least chipmunk over all years and seasons combined to 0.66 for the canyon mouse in the fall of 1994 (Table 7). All equations were significant at the $\underline{P} \leq 0.10$ level, and all but 2 equations were significant at the $\underline{P} \leq 0.05$ level, least chipmunk ($\underline{P}$ = 0.068) and the Colorado chipmunk ($\underline{P}$ = 0.099;

Table 7. Multiple regression equations, adjusted R^2 values, and significance values describing small mammal relative abundance and vegetation relationships over all vegetation types combined, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Species	Equation*	Adjusted R^2	P
Peromyscus maniculatus	0.43 + 0.32(ERS1) -1.36(ERS3)+ 0.13(D)	0.37	0.0000
P. crinitus			
1994 summer	-0.02 + 0.18(ROCK) + 0.24(ERS1)	0.43	0.0132
1994 fall	0.18 + 0.14(ROCK) + 0.16(DCS2)- 0.02(LDX) + 0.25(ERT2)	0.66	0.0038
P. boylei	0.39 + 0.75(ERS3) - 0.15(D)	0.14	0.0107
P. truei	0.04 + 0.13(ERT3)	0.17	0.0163
Neotoma mexicana	0.10 - 0.05(D)	0.13	0.0469
Microtus montanus	0.05 + 0.14(DCT6) + 0.12(ERS2)	0.41	0.0001
Tamias minimus	0.52 - 0.01(LDX)	0.03	0.0680

Table 7. Continued.

T. quadrivittatus	0.18 + 0.28(ERS2)	0.07	0.0987
Overall	1.32 + 0.92(ERS2) - 0.11(ERT5) - 1.72(E)	0.23	0.0000

* ERS1 = Evergreen shrubs in the 0 - 0.5 m height category.

ERS3 = Evergreen shrubs in the > 1 - 2 m height category.

D = Forb cover.

ROCK = Rock cover.

DCS2 = Deciduous shrubs in the > 0.5 - 1 m height category.

LDX = Mean litter depth.

ERT2 = Evergreen trees in the > 0.5 - 1 m height category.

DCT6 = Deciduous trees in the > 15 - 30 m height category.

ERS2 = Evergreen shrubs in the > 0.5 - 1 m height category.

ERT5 = Evergreen trees in the > 5 - 15 m height category.

E = Cactus cover.

Table 7). Only the multiple regression models for the deer mouse, cactus mouse, pinyon mouse, and montane vole exceeded the 0.17 $\underline{R}^2$ value needed to achieve a power of 80% or greater (Table 7).

The regression coefficients that comprised the final regression equation indicate the relative importance of each variable in the equation. The abundance of deer mice increased with an increase in evergreen shrubs in the 0 to 0.5 m height category (ERS1), a decrease in evergreen shrubs in the >1 to 2 m height category (ERS3), and an increase in forbs (D; Table 7).

The abundance of canyon mice in the summer of 1994 increased with an increase in rock cover and ERS1 cover (Table 7). In the fall of 1994, canyon mice abundance increased with an increase in rock cover, deciduous shrubs in the >0.5 to 1.0 m height category (DCS2), evergreen trees in the >0.5 to 1.0 m height category (ERT2), and with a decrease in litter depth (LDX; Table 7).

The abundance of brush mice increased with an increase in ERS3 and a decrease in forbs (Table 7). The abundance of pinyon mice increased with an increase in evergreen trees in the >1 to 2 m height category (ERT3; Table 7).

The abundance of woodrats increased with a decrease in forb cover (Table 7). The abundance of the montane vole increased with an increase in deciduous trees at the >15 to

30 m height category (DCT6) and an increase in evergreen shrubs at the >0.5 to 1 m height category (ERS2; Table 7). The abundance of least chipmunks increased with a decrease in mean litter depth, and the abundance of the Colorado chipmunk increased with an increase in ERS2 (Table 7).

Overall, with all species combined, abundance of small mammals increased with an increase in ERS2, and with a decrease in evergreen trees in the >5 to 15 m height category (ERT5) and cactus cover (E; Table 7).

Logistic regression

The significance level criteria was reached by the inclusion of 1-5 variables for all of the small mammal species within each of the vegetation types analyzed by stepwise logistic regression (Table 8). Correct classification of small mammals being present over all vegetation types ranged from 36.0% to 86.7%, with the lowest percent success occurring in the mixed-mountain brush vegetation type and the highest occurring in the grass-forb/shrub vegetation type (Table 8).

<u>Ponderosa pine vegetation type</u>.--Correct classification for the presence of 2 of the 8 species were 54.3% for the least chipmunk and 62.8% for the deer mouse (Table 8). The presence of deer mice was negatively associated with canopy cover (Table 8) which covered 26.8% of the area (Table 9). The presence of least chipmunks was negatively associated

Table 8. Results of the Wald Chi-square (X^2) for each habitat variable included in the logistic regression model for the presence/absence of each small mammal species within each vegetation type, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Vegetation type Species (n) Variable(s)	Coefficient	X^2	P
Aspen			
Peromyscus maniculatus (165)			
Constant	0.4166	5.9643	0.0146
Forbs	-0.1200	3.0707	0.0797
ERT6	-0.1977	10.0217	0.0015
* % correctly classified for presence/absence = 78.8/41.2			
Microtus montanus (62)			
Constant	-0.9057	9.0456	0.0026
DCT6	0.1345	3.2088	0.0732
DCS1	0.2584	9.0294	0.0027
* % correctly classified for presence/absence = 71.0/67.7			
Tamias minimus (96)			
Constant	-0.1698	0.5950	0.4405
ERT4	-0.1241	2.6076	0.1064

Table 8. Continued.

DCS4	0.0535	0.3868	0.5340
DCT5	0.1711	6.6263	0.0100
* % correctly classified for presence/absence = 47.9/63.5			
Ponderosa Pine			
<u>P</u>. <u>maniculatus</u> (148)			
Constant	0.5880	8.9827	0.0027
Canopy cover	-0.0182	14.0488	0.0002
* % correctly classified for presence/absence = 62.8/54.7			
<u>T</u>. <u>minimus</u> (70)			
Constant	0.2531	0.7170	0.3971
Canopy cover	-0.0141	3.7730	0.0521
Rock	0.7365	5.9795	0.0145
* % correctly classified for presence/absence = 54.3/67.1			
Grass-forb/shrub			
<u>P</u>. <u>maniculatus</u> (152)			
Constant	0.0183	0.0064	0.9261
Grasses	-0.1655	10.6299	0.0011
ERS1	0.1336	4.9689	0.0258
* % correctly classified for presence/absence = 67.1/46.1			
<u>P</u>. <u>boylei</u> (19)			
Constant	-3.2416	4.6462	0.0311
Litter	0.4005	5.1640	0.0231

Table 8. Continued.

* % correctly classified for presence/absence = 73.7/63.2			
M. montanus (30)			
Constant	-0.1314	0.0387	0.8441
DCS2	-0.8341	4.6931	0.0303
ERS1	0.1634	1.2451	0.2645
* % correctly classified for presence/absence = 86.7/53.3			
T. minimus (131)			
Constant	0.4826	8.8968	0.0029
Grasses	-0.3461	18.0197	0.0000
* % correctly classified for presence/absence = 74.8/48.1			
Pinyon-juniper			
P. maniculatus (135)			
Constant	-0.0141	0.0068	0.9343
DCS1	0.1336	3.9788	0.0461
Rock	-0.1890	3.2267	0.0724
* % correctly classified for presence/absence = 39.3/71.9			
P. boylei (98)			
Constant	0.6644	5.2218	0.0223
Bareground	-0.1656	6.9521	0.0084
* % correctly classified for presence/absence = 65.3/53.1			
P. crinitus (65)			
Constant	-0.9675	11.5112	0.0007

Table 8. Continued.

Rock	0.3656	6.2013	0.0005
DCS3	0.5282	12.1969	0.0128
* % correctly classified for presence/absence = 63.1/67.7			
<u>P</u>. <u>truei</u> (73)			
Constant	0.3351	2.7281	0.0986
DCS3	-0.3707	7.7114	0.0055
* % correctly classified for presence/absence = 68.5/50.7			
<u>Neotoma mexicana</u> (23)			
Constant	-0.6555	1.3102	0.2524
Canopy cover	-0.0514	1.5368	0.2151
Cactus	2.6995	5.0474	0.0247
Rock	0.4551	2.4735	0.1158
* % correctly classified for presence/absence = 65.2/73.9			
<u>T</u>. <u>minimus</u> (35)			
Constant	-1.4612	5.2959	0.0214
Litter depth	0.0213	0.4603	0.4975
Litter	0.1059	0.4671	0.4943
DCS1	0.4290	4.2015	0.0404
* % correctly classified for presence/absence = 62.9/85.7			
<u>T</u>. <u>quadrivittatus</u> (56)			
Constant	0.4819	1.3806	0.2400
Litter depth	-0.0910	14.5434	0.0001

Table 8. Continued.

Rock	0.2820	3.0674	0.0799
DCS3	0.2777	4.1081	0.0427
* % correctly classified for presence/absence = 76.8/64.3			
Mixed-conifer			
P. maniculatus (161)			
Constant	0.5634	5.4336	0.0198
Litter depth	-0.0125	2.9181	0.0876
ERT6	-0.2944	12.2909	0.0005
* % correctly classified for presence/absence = 78.3/35.4			
P. boylei (60)			
Constant	0.6984	4.7548	0.0287
Grasses	-0.4717	3.4076	0.0649
ERT4	-0.0349	0.2347	0.6281
ERT5	-0.1255	3.0309	0.0817
Rock	-0.2599	1.9515	0.1624
* % correctly classified for presence/absence = 63.3/58.3			
P. crinitus (31)			
Constant	-0.3747	0.7789	0.3775
Forbs	-0.3110	1.1485	0.2839
Rock	0.2877	2.4616	0.1167
ERS1	0.6685	2.9595	0.0854
ERS2	6.3363	27.1005	0.8151

Table 8. Continued.

DCS3	-0.2902	1.1484	0.2839
* % correctly classified for presence/absence = 58.1/80.7			
T. minimus (49)			
Constant	0.0925	0.1826	0.6691
Rock	-0.3213	1.2584	0.2620
* % correctly classified for presence/absence = 83.7/20.4			
T. quadrivittatus (36)			
Constant	1.8494	3.1281	0.0770
Litter	-0.2183	3.8640	0.0493
Rock	0.1562	0.6221	0.4303
DCS4	-0.9173	2.3851	0.1225
* % correctly classified for presence/absence = 58.3/66.7			
Mixed-mountain brush			
P. maniculatus (167)			
Constant	-0.0724	0.2336	0.6289
Forbs	0.2099	5.7556	0.0164
Rock	-0.4088	7.9402	0.0048
* % correctly classified for presence/absence = 53.3/65.3			
P. boylei (56)			
Constant	0.9186	11.2538	0.0008
Forbs	-0.9307	9.0868	0.0016
Grasses	-0.5221	5.3839	0.0209

Table 8. Continued.

* % correctly classified for presence/absence = 75.0/67.9			
P. crinitus (51)			
Constant	-0.9080	3.4882	0.0618
Grasses	-0.7120	8.9642	0.0028
Rock	0.6429	7.3225	0.0068
DCS3	0.2078	6.3848	0.0115
* % correctly classified for presence/absence = 70.6/66.7			
N. mexicana (10)			
Constant	-1.2003	1.5084	0.2194
ERS1	0.1693	0.3486	0.5549
DCS3	0.1727	1.4185	0.2337
* % correctly classified for presence/absence = 60.0/70.0			
T. minimus (25)			
Constant	-0.2192	0.4694	0.4933
ERT3	0.2855	1.9899	0.1583
* % correctly classified for presence/absence = 36.0/80.0			
T. quadrivittatus (28)			
Constant	1.6429	7.2878	0.0069
Litter depth	-0.0471	4.9149	0.0266
Forbs	-0.8458	3.5078	0.0611
* % correctly classified for presence/absence = 78.6/53.6			
Riparian			

Table 8. Continued.

_P_. _maniculatus_ (146)			
Constant	0.0743	0.3208	0.5711
ERT3	-0.1530	1.5558	0.2123
* % correctly classified for presence/absence = 74.7/29.5			
_P_. _crinitus_ (38)			
Constant	0.3031	0.9738	0.3237
Litter depth	-0.0185	2.1234	0.1451
* % correctly classified for presence/absence = 76.3/47.4			
_T_. _minimus_ (23)			
Constant	-0.8478	1.6999	0.1923
Forbs	-0.1511	0.2455	0.6202
Litter depth	0.0364	3.4753	0.0623
* % correctly classified for presence/absence = 60.9/60.9			
_T_. _quadrivittatus_ (22)			
Constant	1.2139	5.8705	0.0154
Litter depth	-0.0775	4.3253	0.0376
DCT3	-0.5596	0.9733	0.3239
* % correctly classified for presence/absence = 86.4/54.6			

with canopy cover and positively associated with rock cover (Table 8). Canopy covered 27.9% of the area and rocks covered 4.8% of the area (Table 9).

<u>Aspen vegetation type</u>.--Within the aspen vegetation type, correct classification for the presence of three of the eight small mammal species ranged from 78.8% for the deer mouse to 71.0% for the mountain vole (Table 8). The presence of deer mice was negatively associated with forb cover and ERT6 cover (Table 8). Forbs covered 15.3% of the area and ERT6 covered 5.0% of the area (Table 9). The presence of montane voles was positively associated with DCS1 and with DCT6 cover (Table 8). DCS1 covered 30.8% of the area and DCT6 covered 22.0% of the area (Table 9). Least chipmunks were negatively associated with ERT4 cover, positively associated with DCS4, and with deciduous trees in the >5 to 15 m height category (DCT5; Table 8). ERT4 covered 6.7% of the area, DCS4 covered 8.0% of the area, and DCT5 covered 19.7% of the area where least chipmunks were present (Table 9).

<u>Grass-forb/shrub vegetation type</u>.--Within the grass-forb/shrub vegetation type, correct classification for the presence of 4 of the 8 small mammal species ranged from 62.1% for the deer mouse to 86.7% for the mountain vole (Table 8). The presence of deer mice was negatively associated with grasses and positively associated with ERS1 (Table 8).

Table 9. Means (± SD) and mean percent cover (± SD) of all used (P) and non-used (A) vegetation variables included in each logistic regression model for each small mammal species within each vegetation type, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Vegetation type Species Grouped variable (code) Variable (code)	P $\overline{\underline{X}}$(±SD) A $\overline{\underline{X}}$(±SD)	P $\overline{\underline{X}}$ % Cover (±SD) A $\overline{\underline{X}}$ % Cover (±SD)
Pinyon-juniper		
Peromyscus maniculatus		
Rock (ROCK)	0.64(1.06)	5.8(9.64)
	0.96(1.37)	7.3(12.45)
Deciduous shrubs (DCS1)	1.52(2.32)	13.8(21.09)
	1.01(1.63)	9.2(14.82)
Mahogany spp.	0.36(0.93)	3.3(8.45)
	0.24(0.63)	2.2(5.73)
Squawbush	0.04(0.30)	0.4(2.73)
	0.04(0.30)	0.4(2.73)
Wild rose	0.01(0.09)	0.1(0.82)
	0.01(0.05)	0.1(0.45)
Utah Serviceberry	0.20(0.53)	1.8(4.82)

Table 9. Continued.

	0.10(0.35)	0.9(3.18)
Gambel oak	0.88(1.97)	8.0(17.91)
	0.54(1.36)	4.9(12.36)
Snowberry	0.10(0.34)	0.9(3.09)
	0.08(0.32)	0.7(2.91)
Dogwood	---	

P. boylei		
bareground (BG)	3.56(2.38)	32.4(21.64)
	4.33(2.44)	39.4(22.18)
P. crinitus		
rock (ROCK)	1.54(1.63)	14.0(14.82)
	0.76(1.20)	6.9(10.91)
Deciduous shrubs 3 (DCS3)	1.86(1.91)	16.9(17.36)
	1.03(1.53)	9.4(13.91)
Mahogany spp.	0.82(1.25)	7.5(11.36)
	0.32(0.80)	2.9(7.27)
Squawbush	0.03(0.17)	0.3(1.55)
	0.03(0.20)	0.3(1.82)
Utah Serviceberry	0.26(0.54)	2.4(4.91)
	0.12(0.39)	1.1(3.55)
	0.04(0.24)	0.4(2.18)

Table 9. Continued.

Gambel oak	0.75(1.44)	6.8(13.09)
	0.54(1.29)	4.9(11.73)
Dogwood	---	

P. truei		
Deciduous shrubs 3 (DCS3)	0.60(1.09)	5.5(9.91)
	1.24(1.67)	11.3(15.18)
Mahogany spp.	0.48(0.94)	4.4(8.55)
	0.36(0.75)	3.3(6.82)
Squawbush	0.33(0.80)	3.0(2.72)
	0.05(0.26)	0.5(2.36)
Utah Serviceberry	0.26(0.54)	2.4(4.91)
	0.12(0.39)	1.1(3.55)
	0.04(0.24)	0.4(2.18)
Gambel oak	0.75(1.44)	6.8(13.09)
	0.54(1.29)	4.9(11.73)
Dogwood	---	

Neotoma mexicana		
cactus (E)	0.30(0.47)	2.7(4.27)
	0.13(0.38)	1.2(3.55)
rock (ROCK)	1.39(1.23)	12.6(11.18)

Table 9. Continued.

	0.84(1.29)	7.6(11.73)
mean canopy cover (CCX)	3.44(5.53)	
	8.43(11.40)	
<u>Tamias minimus</u>		
litter(LI)	6.71(2.87)	61.0(26.09)
	4.96(2.92)	45.1(26.55)
mean litter depth (LDX)	26.63(18.86)	
	16.87(15.97)	
Deciduous shrubs 1 (DCS1)	2.20(2.53)	20.0(23.0)
	1.07(1.78)	9.7(16.18)
Mahogany spp.	0.74(1.31)	6.7(11.91)
	0.24(0.65)	2.2(5.91)
Squawbush	0.09(0.51)	0.8(4.64)
	0.03(0.27)	0.3(2.45)
Wild rose	---	
	0.01(0.07)	0.1(0.64)
Utah Serviceberry	0.34(0.73)	3.1(6.64)
	0.09(0.34)	0.8(3.09)
Gambel oak	0.91(2.04)	8.3(18.55)
	0.62(1.52)	5.6(13.82)
Snowberry	0.11(0.40)	1.0(3.64)
	0.08(0.32)	0.7(2.91)

Table 9. Continued.

Dogwood	---	

T. quadrivittatus		
rock (ROCK)	1.73(1.66)	15.7(15.09)
	0.75(1.20)	6.8(10.91)
mean litter depth (LDX)	9.87(8.13)	
	18.62(16.92)	
Deciduous shrubs 3 (DCS3)	1.80(1.88)	16.4(17.09)
	1.06(1.56)	9.6(14.18)
Mahogany spp.	0.89(1.30)	8.1(11.82)
	0.33(0.80)	3.0(7.27)
Squawbush	---	
	0.05(0.25)	0.5(2.27)
Utah Serviceberry	0.14(0.40)	1.3(3.64)
	0.14(0.42)	1.3(3.82)
Gambel oak	0.77(1.58)	7.0(14.36)
	0.54(1.27)	4.9(11.55)
Dogwood	---	

Mixed-conifer		
P. maniculatus		
mean litter depth (LDX)	27.03(14.21)	

Table 9. Continued.

	32.99(19.73)	
Evergreen trees 6 (ERT6)	0.40(1.09)	3.6(9.91)
	1.20(2.24)	10.9(20.36)
ponderosa pine	0.11(0.55)	1.0(5.0)
	0.39(1.09)	3.5(9.91)
pinyon pine	---	
	---	
douglas fir	0.29(0.89)	2.6(8.09)
	0.81(1.94)	7.4(17.64)
juniper spp.	---	

P. boylei		
grasses (M)	0.25(0.63)	2.3(5.73)
	0.61(1.20)	5.5(10.91)
rock (ROCK)	0.38(0.78)	3.5(7.09)
	0.65(1.50)	5.9(13.64)
Evergreen trees 4 (ERT4)	2.72(2.73)	24.7(24.82)
	3.39(3.28)	30.8(29.82)
ponderosa pine	0.10(0.35)	0.9(3.18)
	0.44(1.24)	4.0(11.27)
pinyon pine	0.10(0.48)	0.9(4.36)
	0.15(0.70)	1.4(6.36)

Table 9. Continued.

douglas fir	2.10(2.65)	19.1(24.09)
	2.29(3.00)	20.8(27.27)
juniper spp.	0.38(1.04)	3.5(9.45)
	0.51(1.16)	4.6(10.55)
Evergreen trees 5 (ERT5)	1.83(2.86)	16.6(26.0)
	2.53(3.30)	23.0(30.0)
ponderosa pine	0.07(0.41)	0.6(3.73)
	0.68(1.79)	6.2(16.27)
pinyon pine	---	
	0.09(0.81)	0.8(7.36)
douglas fir	1.68(2.64)	15.3(24.0)
	1.61(2.82)	14.6(25.64)
juniper spp.	0.08(0.53)	0.7(4.82)
	0.15(0.76)	1.4(6.91)
<u>P</u>. <u>crinitus</u>		
forbs(D)	0.32(0.95)	2.9(8.64)
	0.70(1.07)	6.4(9.73)
rock (ROCK)	---	
	0.58(1.37)	5.3(12.45)
Evergreen shrubs 1 (ERS1)	1.10(1.38)	10.0(12.55)
	0.38(0.89)	3.5(8.09)
Holy sp.	---	

Table 9. Continued.

	0.01(0.13)	0.1(1.18)
Buffaloberry	0.19(0.75)	1.7(6.82)
	0.01(0.20)	0.1(1.82)
Sagebrush	---	
	0.04(0.33)	0.4(3.0)
Rabbitbrush	0.03(0.18)	0.3(1.64)
	0.01(0.07)	0.1(0.64)
Mormon tea	0.03(0.18)	0.3(1.64)
	0.01(0.07)	0.1(0.64)
Oregon grape	0.84(1.29)	7.6(11.73)
	0.31(0.81)	2.8(2.82)
Bitterbrush	---	

Evergreen shrubs 2 (ERS2)	0.32(0.70)	2.9(6.36)
	0.05(0.26)	0.5(0.45)
Holy sp.	---	
	0.01(0.07)	0.1(0.64)
Buffaloberry	0.26(0.68)	2.4(6.18)
	0.02(0.19)	0.2(1.73)
Sagebrush	---	
	0.01(0.10)	0.1(0.91)
Rabbitbrush	---	

Table 9. Continued.

Mormon tea	---	

Oregon grape	0.07(0.25)	0.6(2.27)
	0.02(0.15)	0.2(1.36)
Bitterbrush	---	

Deciduous shrubs 3 (DCS3)	0.65(1.11)	5.9(10.09)
	1.38(1.92)	12.5(17.45)
Mahogany spp.	0.16(0.37)	1.5(3.36)
	0.11(0.49)	1.0(4.45)
Squawbush	---	
	0.02(0.27)	0.2(2.45)
Utah Serviceberry	0.13(0.43)	1.2(3.91)
	0.17(0.57)	1.5(5.18)
Gambel oak	0.36(0.80)	3.3(7.27)
	1.08(1.70)	9.8(15.45)
Dogwood	---	

<u>T. minimus</u>		
rock (ROCK)	0.20(0.50)	1.8(4.55)
	0.67(1.50)	6.1(13.64)

Table 9. Continued.

T. quadrivittatus		
litter(LI)	6.69(3.74)	60.8(34.0)
	8.57(2.70)	77.9(24.55)
rock (ROCK)	1.69(2.60)	15.4(23.64)
	0.53(1.26)	4.8(11.45)
Deciduous shrubs 4 (DCS4)	0.11(0.32)	1.0(2.91)
	0.64(1.46)	5.8(13.27)
Mahogany spp.	0.03(0.17)	0.3(1.55)
	0.02(0.13)	0.2(1.18)
Squawbush	---	

Utah Serviceberry	---	
	0.02(0.22)	0.2(2.0)
Gambel oak	0.08(0.28)	0.7(2.55)
	0.60(1.46)	5.5(13.27)
Dogwood	---	

Mixed-mountain brush		
P. maniculatus		
forbs(D)	1.22(1.41)	11.1(12.82)
	0.78(1.17)	7.1(10.64)
rock (ROCK)	0.21(0.64)	1.9(5.82)

Table 9. Continued.

	0.52(1.12)	4.7(10.18)
P. boylei		
grasses (M)	0.34(0.77)	3.1(7.0)
	1.06(1.34)	9.6(12.18)
forbs(D)	0.25(0.55)	2.3(5.0)
	1.08(1.34)	9.8(12.18)
P. crinitus		
grasses (M)	0.33(0.79)	3.0(7.18)
	1.05(1.46)	9.5(13.27)
rock (ROCK)	0.80(1.37)	7.3(12.45)
	0.33(0.87)	3.0(7.91)
Deciduous shrubs 3 (DCS3)	5.35(3.17)	48.6(28.82)
	4.23(2.85)	38.5(25.91)
Mahogany spp.	1.20(1.48)	10.9(13.45)
	0.54(1.21)	4.9(11.0)
Squawbush	0.02(0.14)	0.2(12.73)
	0.00(0.05)	0.0(0.45)
Utah Serviceberry	0.53(1.14)	4.8(10.36)
	0.38(0.93)	3.5(8.45)
Gambel oak	3.61(2.93)	32.8(2.66)
	3.31(2.73)	30.1(24.82)
Dogwood	---	

Table 9. Continued.

N. mexicana		
Evergreen shrubs 1 (ERS1)	1.50(1.78)	13.6(16.18)
	0.56(1.14)	5.1(10.36)
Holy sp.	---	

Buffaloberry	---	
	0.03(0.21)	0.3(1.91)
Sagebrush	0.10(0.32)	0.9(2.91)
	0.29(0.79)	2.6(7.18)
Rabbitbrush	---	

Mormon tea	---	
	0.01(0.07)	0.1(0.64)
Oregon grape	1.40(1.84)	12.7(16.73)
	0.24(0.89)	2.2(8.09)
Bitterbrush	---	

Deciduous shrubs 3 (DCS3)	6.90(3.48)	62.7(31.64)
	4.31(2.87)	39.2(26.09)
Mahogany spp.	1.30(1.49)	11.8(13.55)
	0.61(1.26)	5.5(11.45)

Table 9. Continued.

Squawbush	---	
	0.01(0.07)	0.1(0.64)
Utah Serviceberry	0.60(0.70)	5.5(6.36)
	0.39(0.97)	3.5(8.82)
Gambel oak	5.00(3.20)	45.5(29.09)
	3.30(2.73)	30.0(24.82)
Dogwood	---	

<u>T</u>. <u>minimus</u>		
Evergreen trees 3 (ERT3)	1.16(1.89)	10.5(17.18)
	0.66(1.57)	6.0(14.27)
ponderosa pine	---	
	0.03(0.22)	0.3(2.0)
pinyon pine	0.40(1.12)	3.6(10.18)
	0.11(0.53)	1.0(4.82)
douglas fir	0.16(0.80)	1.5(7.27)
	0.04(0.41)	0.4(3.73)
juniper spp.	0.60(1.32)	5.5(12.0)
	0.49(1.37)	4.5(12.45)
<u>T</u>. <u>quadrivittatus</u>		
forbs(D)	0.29(0.54)	2.6(4.91)
	0.97(1.29)	8.8(11.73)

Table 9. Continued.

mean litter depth (LDX)	18.42(12.51)	
	33.89(18.56)	
Riparian		
P. maniculatus		
Evergreen trees 3 (ERT3)	0.42(0.88)	3.8(8.0)
	0.67(1.14)	6.1(10.36)
ponderosa pine	0.03(0.22)	0.3(2.0)
	0.10(0.42)	0.9(3.82)
pinyon pine	0.01(0.08)	0.1(0.73)
	0.00(0.06)	0.0(0.55)
douglas fir	0.10(0.54)	0.9(4.91)
	0.14(0.65)	1.3(5.91)
juniper spp.	0.27(0.68)	2.5(6.18)
	0.43(0.86)	3.9(7.82)
P. crinitus		
mean litter depth (LDX)	13.34(18.62)	
	22.26(23.04)	
T. minimus		
forbs(D)	0.35(0.71)	3.2(6.45)
	0.99(1.32)	9.0(12.0)
mean litter depth (LDX)	32.22(18.76)	
	20.75(22.86)	

Table 9. Continued.

T. quadrivittatus		
mean litter depth (LDX)	6.59(5.56)	
	22.27(23.11)	
Deciduous trees 3 (DCT3)	0.14(0.35)	1.3(3.18)
	1.16(1.77)	10.5(16.09)
Willow spp.	---	
	0.24(0.72)	2.2(6.55)
Aspen	---	
	0.01(0.07)	0.1(0.64)
Maple spp.	0.14(0.35)	1.3(3.18)
	0.08(0.37)	0.7(3.36)
Water birch	---	
	0.83(1.60)	7.5(14.55)
Single-leaf ash	---	

Aspen		
P. maniculatus		
forbs(D)	1.68(1.44)	15.3(13.09)
	2.20(1.99)	20.0(18.09)
Evergreen trees 6 (ERT6)	0.55(1.68)	5.0(15.27)
	1.31(2.30)	11.9(20.91)
ponderosa pine	0.55(1.68)	5.0(15.27)

Table 9. Continued.

	1.31(2.30)	11.9(20.91)
pinyon pine	---	
	---	
douglas fir	---	
	---	
juniper spp.	---	

<u>Microtus</u> <u>montanus</u>		
Deciduous trees 6 (DCT6)	2.42(2.94)	22.0(26.73)
	1.20(2.46)	10.9(22.36)
Aspen	2.42(2.94)	22.0(26.73)
	1.20(2.46)	10.9(22.36)
Deciduous shrubs 1 (DCS1)	3.39(2.44)	30.8(22.18)
	2.10(2.35)	19.1(21.36)
Mahogany spp.	---	

Squawbush	---	

Wild rose	---	
	0.02(0.14)	0.2(1.27)
Utah Serviceberry	---	

Table 9. Continued.

Gambel oak	0.11(0.48)	1.0(4.36)
	0.08(0.37)	0.7(3.36)
Snowberry	3.27(2.31)	29.7(21.0)
	2.00(2.20)	18.2(20.0)
Dogwood	---	

<u>T</u>. <u>minimus</u>		
Evergreen trees 4 (ERT4)	0.74(1.58)	6.7(14.36)
	1.41(2.47)	12.8(22.45)
ponderosa pine	0.74(1.58)	6.7(14.36)
	1.41(2.47)	12.8(22.45)
pinyon pine	---	
	---	
douglas fir	---	
	---	
juniper spp.	---	

Deciduous trees 5 (DCT5)	2.17(3.07)	19.7(27.91)
	1.48(2.30)	13.5(20.91)
Aspen	2.17(3.07)	19.7(27.91)
	1.48(2.30)	13.5(20.91)
Maple spp.	---	

Table 9. Continued.

Deciduous shrubs 4 (DCS4)	0.88(1.86)	8.0(16.91)
	0.42(1.21)	3.8(11.0)
Mahogany spp.	---	

Squawbush	---	

Utah Serviceberry	---	

Gambel oak	0.88(1.86)	8.0(16.91)
	0.42(1.21)	3.8(11.0)
Dogwood	---	

Ponderosa pine		
<u>P</u>. <u>maniculatus</u>		
mean canopy cover (CCX)	26.87(25.60)	
	38.73(24.43)	
<u>T</u>. <u>minimus</u>		
rock (ROCK)	0.53(1.02)	4.8(9.27)
	0.25(0.70)	2.3(6.36)
mean canopy cover (CCX)	27.93(24.83)	
	35.71(25.45)	

Table 9. Continued.

Grass-forb/shrub		
<u>P</u>. <u>maniculatus</u>		
grasses (M)	0.78(1.85)	7.1(16.82)
	0.46(1.32)	4.2(12.0)
Evergreen shrubs 1 (ERS1)	3.16(2.37)	28.7(21.55)
	1.97(1.88)	17.9(17.09)
Holy sp.	---	

Buffaloberry	---	

Sagebrush	3.13(2.39)	28.5(21.73)
	1.93(1.89)	17.5(17.18)
Rabbitbrush	---	

Mormon tea	---	

Oregon grape	---	
	0.02(0.14)	0.2(1.27)
Bitterbrush	0.03(0.18)	0.3(1.64)
	0.02(0.14)	0.2(1.27)
<u>P</u>. <u>boylei</u>		
litter(LI)	9.00(1.73)	81.8(15.73)

Table 9. Continued.

	7.20(2.35)	65.5(21.36)
M. montanus		
Evergreen shrubs 1 (ERS1)	4.23(2.03)	38.5(18.45)
	2.62(2.26)	23.8(20.55)
Holy sp.	---	

Buffaloberry	---	

Sagebrush	4.20(2.06)	38.2(18.73)
	2.59(2.27)	23.5(20.64)
Rabbitbrush	---	

Mormon tea	---	

Oregon grape	---	
	0.01(0.09)	0.1(0.82)
Bitterbrush	0.03(0.18)	0.3(1.64)
	0.03(0.17)	0.3(1.55)
Deciduous shrubs 2 (DCS2)	0.20(0.55)	1.8(5.0)
	1.33(1.73)	12.1(15.73)
Mahogany spp.	---	
	0.08(0.42)	0.7(19.55)

Table 9. Continued.

Squawbush	---	

Wild rose	---	

Utah Serviceberry	0.20(0.55)	1.8(5.0)
	0.96(1.43)	8.7(13.0)
Gambel oak	---	
	0.29(1.05)	2.6(9.55)
Snowberry	---	

Dogwood	---	

T. minimus		
grasses (M)	0.89(1.19)	8.1(10.82)
	2.27(3.02)	20.6(27.45)

Grasses covered 11.4% of the area and ERS1 covered 28.7% of the area (Table 9). The presence of brush mice was positively associated with litter cover (Table 8) which covered 81.8% of the area (Table 9).

The montane vole was negatively associated with deciduous shrubs in the >0.5 to 1.0 m height category (DCS2) and positively associated with ERS1 (Table 8). DCS2 covered 1.8% and ERS1 covered 38.5% of the area where mountain voles were present (Table 9). Grasses with a cover of 8.1% were negatively associated with the presence of least chipmunks (Table 8 and 9).

Pinyon-juniper vegetation type.--Correct classification of 7 out of the 8 small mammal species being present within the pinyon-juniper vegetation type ranged from 39.3% for the deer mouse to 76.8% for the Colorado chipmunk (Table 8). Deciduous shrubs in the 0 to 0.5 m height category (DCS1)and in the >1 to 2 m height category (DCS3), rock, and bareground were variables included in the logistic regression models for the 4 *Peromyscus* species (Table 8).

Both rock and DCS3 cover were positively associated with the presence of canyon mice (Table 8). Deciduous shrubs in this, height category covered 16.9% of the area, 14.0% of the area was covered by rock (Table 9). Deer mice were negatively associated with rock cover and positively associated with DCS1 (Table 8). Rock covered 5.8% of the

area and DCS1 covered 13.8% of the area where deer mice were present (Table 9). Pinyon mice were negatively associated with DCS3 (Table 8) which covered 5.5% of the area where they were present (Table 9). Brush mice were positively associated with bareground (Table 8) which covered 32.4% of the area where they were present (Table 9).

Mexican woodrats were negatively associated with canopy cover and positively associated with cacti and rock cover (Table 8). Mean percent canopy cover was 8.2%, cacti cover was 2.7%, and rock cover was 12.6% of the area where Mexican woodrats were present (Table 9).

The presence of least chipmunks was positively associated with litter, deciduous shrubs in the 0 to 0.5 m height category (DCS1), and litter depth (Table 8). Litter depth mean was approximately 26 mm, litter covered 61% of the area, and DCS1 covered 20.0% of the area where least chipmunks were present (Table 9). The presence of Colorado chipmunks was negatively associated with litter depth, and positively associated with DCS3 and rock cover (Table 8). Mean litter depth was approximately 10 mm, rock covered 15.7% of the area, and DCS3 was 16.4% of the area where Colorado chipmunks were present (Table 9).

<u>Mixed-conifer</u> <u>vegetation</u> <u>type</u>.--In the mixed-conifer vegetation type, 5 out of the 8 small mammal species being present in this vegetation type had correct classifications

that ranged from 58.1% for the canyon mouse to 83.7% for the least chipmunk (Table 8). The deer mouse and brush mouse both had negative associations with all of the variable(s) in their models. The logistic regression model for the brush mouse included grass cover, rock cover, and evergreen trees in the >2 to 5 m height category (ERT4) and the >5 to 15 m height category (ERT5; Table 8). Rock and grass covered 3.5% and 2.3% of the area, respectively, while ERT4 covered 24.7% of the area, and ERT5 covered 16.6% of the area (Table 9). The variables associated with the deer mouse model were litter depth and evergreen trees in the >15 to 30 m height category (ERT6) (Table 8). Mean litter depth was approximately 27 mm and ERT6 covered 3.6% of the area (Table 9).

Forb, rock, DCS3, ERS1, and ERS2 cover were associated with the presence of the canyon mouse (Table 8). Both the forb cover and DCS3 cover had a negative association with the presence of canyon mice (Table 8). Forbs covered 2.9% of the area, and DCS3 covered 5.9% of the area (Table 9). Rock cover, ERS1, and ERS2 cover were all positively associated with the presence of canyon mice (Table 8). Rock covered 11.2% of the area, ERS1 covered 10.0% of the area, and ERS2 covered 2.9% of the area (Table 9).

The least chipmunk was negatively associated with rock, (Table 8) which covered 1.8% of the area (Table 9). The

presence of Colorado chipmunks were positively associated with rock cover and negatively associated with litter and with deciduous shrubs in the >2 to 5 m height category (DCS4) (Table 8). Litter covered 60.8%, rock covered 15.4%, and DCS4 covered 1.0% of the area where Colorado chipmunks were present (Table 9).

Mixed-mountain vegetation type.--Within the mixed-mountain brush vegetation type, 6 out of the 8 small mammal species had correct classifications in regards to their presence in this vegetation type that ranged from 36.0% for the least chipmunk to 78.6% for the Colorado chipmunk (Table 8). The deer mouse and the brush mouse were associated with forb species. The deer mouse was positively associated with forb cover and negatively associated with rock cover (Table 8). Forbs covered 11.1% of the area and rocks covered 1.9% of the area where deer mice were present (Table 9). The brush mouse was negatively associated with forb and grass cover (Table 8). Forbs covered 2.3% and grasses covered 3.1% of the area where brush mice were present (Table 9). Canyon mice were negatively associated with grass cover and positively associated with rock and DCS3 cover (Table 8). Grasses covered 3.0% of the area, rocks covered 7.3% of the area, and DCS3 covered 48.6% of the area where canyon mice were present (Table 9).

The presence of Mexican woodrats was positively

associated with ERS1 cover and DCS3 cover (Table 8) with ERS1 covering 13.6% of the area and DCS3 covering 62.7% of the area (Table 9). The least chipmunk was positively associated with evergreen trees in the >1 to 2 m height category (ERT3; Table 8) with ERT3 covering 10.5% of the area (Table 9). The presence of Colorado chipmunks was negatively associated with a mean litter depth (Table 8) of approximately 18 mm and forbs (Table 8) covering 3.5% of the area (Table 9).

Riparian vegetation type.--In the riparian vegetation type, correct classification for 4 out of the 8 small mammal being present ranged from 61.9% for the least chipmunk to 86.4% for the Colorado chipmunk (Table 8). The presence of deer mice was negatively associated with evergreen trees in the >1 to 2 m height category (Table 8) which covered 3.7% of the area (Table 9). The presence of canyon mice was negatively associated with a mean litter depth (Table 8) of approximately 13 mm (Table 9).

The presence of least chipmunks was negatively associated with forbs and positively associated with mean litter depth (Table 8). Forbs covered 3.2% of the area and mean litter depth was approximately 32 mm (Table 9). The presence of Colorado chipmunks was negatively associated with both a mean litter depth (Table 8) of approximately 7 mm (Table 9) and deciduous trees in the >1 to 2 m height category (DCT3; Table 8) which covered 1.3% of the area

(Table 9).

DISCUSSION

Relative Abundances - Canyons and Mesas

The primary objective of our study was to examine, at a macro-scale, Mexican spotted owl prey species' distribution and abundance based on the Mexican spotted owls second- and third-orders of habitat selection (home ranges and habitat components within home ranges, respectively). More specifically, we determined and compared relative abundances of small mammals (primarily Mexican spotted owl prey species) within Mexican spotted owls home ranges. Within these home ranges we surveyed between the canyons and mesas, and between vegetation types occurring in both of these areas.

Relative abundances of small mammal species only differed in the canyons between summer and fall in 1994 (with the fall having a higher abundance than the summer). Annual differences in abundance occurred only on the mesas between the fall of 1994 and the fall of 1995. Seasonal and annual differences in have been observed in small mammal populations (Rosenweig and Winakur 1969, O'Farrell 1974, Kelt et al. 1994, Skupski 1995). These observations may be influenced by any number of abiotic environmental factors, predator populations, or food availability in any particular season or year (O'Farrell 1974, Van Horne 1983, Ward and Block 1995).

Differences between the canyons and mesas were only

observed in the fall seasons with 1994 having a higher abundance in the canyons and 1995 having a higher abundance on the mesas. Even though these 2 areas, the canyons and mesas, are adjacent to eachother (no more than 3.2 km [2 miles] apart), environmental factors, predators, and food availability may be quite different between the areas. Therefore, the factors that influence abundances between seasons and years may be affecting the canyons and mesas in different ways.

Differences between vegetation types in the canyons were not observed. On the mesas, however, differences were observed primarily between the grass-forb/shrub vegetation type and the ponderosa pine and aspen vegetation types, with the grass-forb/shrub vegetation type having a higher abundance of animals than the others. The absence of differences between canyon vegetation types may be due to the close proximity of each of these vegetation types to each other, such that the home ranges of small mammals may encompass more than one particular vegetation type. In any case, what was most important within the canyons was that woodrats, the owl's primary prey species, were predominantly captured in the pinyon-juniper vegetation type.

On the mesas, the grass-forb/shrub vegetation type consisted primarily of sagebrush and was heavily used by cattle. The deer mouse is described by Fitzgerald et al.

(1994) as being able to easily adapt and exploit disturbed areas such as areas that have been heavily grazed. Coincidentally, the deer mouse had its highest abundance in this vegetation type. The least chipmunk, which was also very abundant in this vegetation type, is typically associated with open, sunny areas (Fitzgerald et al. 1994) as is characteristic of the grass-forb/shrub vegetation type.

Relative Abundances - Species Specific

The deer mouse was the most abundant species in all of the 11 vegetation types sampled, which corroborates with the literature describing the deer mouse as inhabiting a wide range of vegetation types and being the most common small mammal in North America (Burt and Grossenheider 1976, Hoffmeister 1986, Fitzgerald et al. 1994). Fitzgerald et al. (1994) noted that where Peromyscus species' that are habitat specific occur, deer mice will be locally scarce or absent. This was not the case in our study where in 9 of the vegetation types deer mice were more abundant than any of the other 3 more specialized Peromyscus species captured. However, Armstrong (1979) noted that it is not uncommon for Peromyscus species to co-occur in areas where the vegetation is heterogeneous, as is found within the canyons in our study area. For example, the mixed-conifer vegetation type within the canyons may have scattered pinyon pines or patches of Gambel oak within them.

The brush mouse was most abundant in the pinyon-juniper vegetation type which is characteristic of the species habitat which consist of rough, broken terrain with boulders and heavy brush (Wilson 1968, Hoffmeister 1986, Fitzgerald et al. 1994). The brush mouse was also abundant in the riparian vegetation type where the stream beds consisted of heavy brush and rocks.

Canyon mice were almost equally abundant in the mixed-conifer, pinyon-juniper, and mixed-mountain brush vegetation types. However, these vegetative characteristics contradict the rocky, slickrock, and cliff habitats associated with this species (Hoffmeister 1986, Johnson and Armstrong 1987, Fitzgerald et al. 1994). This may be due to the close proximity of these vegetation types to the cliff walls and slickrock. Also, the vegetation types in the canyons were rocky. For example, the mixed-conifer vegetation type was always along the steep sides of the canyons and often contained large boulders within small drainages that ran through the vegetation type. Johnson and Armstrong (1987) noted that the vegetation in an area may have little or no effect on the the local distribution of this species, but that, the species is associated with the rocky substrate of the area rather than the plant association.

The pinyon mouse was most abundant in the pinyon-juniper vegetation type in our study, as is characteristic of the

species throughout its range (Wilson 1968, Burt and Grossenheider 1976, Armstrong 1979, Hoffmeister 1986, Fitzgerald et al. 1994).

The Mexican woodrat is generally found on rocky slopes, cliffs, and rock outcrops (Burt and Grossenheider 1976) and is also associated with pinyon-juniper woodlands (Cornely and Baker 1979, Armstrong 1979, Fitzgerald et al. 1994). In our study, the Mexican woodrat was most abundant in habitats described above, being predominantly captured in the pinyon-juniper vegetation type.

The montane vole was most abundant on the mesas in the aspen vegetation type. These observations agree with habitats typically associated with the montane vole, consisting of moist to wet areas with thick forb and grass cover, including aspen stands (Hoffmeister 1986, Fitzgerald et al. 1994).

The least chipmunk was abundant in all of the 11 vegetation types sampled, being most abundant on the mesas, especially within the grass-forb/shrub vegetation type. Fitzgerald et al. (1994) noted that the least chipmunk ranges over a wide area and in many different habitat types including semi-desert shrublands, montane woodlands and shrublands, and forest edge. Within this range of vegetation types, the least chipmunk generally occupies relatively open sunny areas on the edge of escape cover (Fitzgerald et al.

1994) which is characteristic of the grass-forb/shrub vegetation type.

The Colorado chipmunk was most abundant in the pinyon-juniper vegetation type, which typifies its general distribution. Best et al. (1994) describe a variety of habitats in which the Colorado chipmunk was found, woodlands represented 36% of the areas occupied by the species. Lechleitner (1969) associated the Colorado chipmunk with pinyon-juniper and spruce-fir forests, and open, rocky, brushy areas. In addition, Fitzgerald et al. (1994) associated the Colorado chipmunk with broken terrain and canyons.

Vegetative Characteristics - Micro-scale

<u>Multiple</u> <u>regression</u>.--Of the 8 species used in stepwise multiple regression analyses, only 5 models exceeded the $\underline{R}^2$ value of 0.17 necessary to achieve a power of at least 80%. Therefore, only those models with a power > 80%. In general, the variables making up the final models for each of the species are consistent with the literature. For example, the model for the pinyon mouse contained a vegetation variable that corresponds to the vegetative characteristics described in the literature with respect to its habitat: it increased in abundance with an increase in evergreen trees such as pinyon pines and junipers (Wilson 1968, Armstrong 1979, Fitzgerald et al. 1994).

The deer mouse model contains variables that are non-specific to a particular vegetation type which corresponds to its abundance in all of the vegetation types in this study. The montane vole does have more specific habitat characteristics which agree with the variables in its multiple regression model, such as deciduous trees (aspen) in the aspen vegetation type where it was most abundant, and evergreen shrubs such as sagebrush in the grass-forb/shrub vegetation type where it was also abundant. These habitat characteristics reflect or include the requirements presented in the literature for the occurrence of these species (Armstrong 1979, Hoffmeister 1986, Fitzgerald et al. 1994).

Logistic regression.--As noted in the introduction, we expected species to respond to different vegetative characteristics within specific vegetation types, and this was the case. In general, only 1 vegetation type, the pinyon-juniper vegetation type, contained groups of variables that more than 2 species of small mammals had in common. Within the rest of the vegetation types, vegetation variables could not be grouped for each vegetation type. A group of variables would make management of an area for specific species much easier than trying to manipulate vegetation for 1 or 2 species.

We must remember, however, that the variables within each model associated with each species are only valid when

in coexistence with the other variables in the model. What we were attempting to do, however, is develop a basis for managing each vegetation type for more than one group of species. A problem with these models that may jepordize the validity of our results, is the small sample size of the dependent variable compared to the number of independent variables (Johnson 1981, Morrison et al. 1992:329-330). These models should therefore be considered purely as descriptive, rather than predictive representations of habitat requirements for the small mammals used in these analyses.

Within the pinyon-juniper vegetation type, rocky and open areas generally described the presence of 4 of the 7 species of small mammals. These species, the canyon mouse, brush mouse, Mexican woodrat, and the Colorado chipmunk, are all associated with open rocky areas (Wilson 1968, Armstrong 1979, Hoffmeister 1986, Johnson and Armstrong 1987, Fitzgerald et al. 1994). Deciduous shrubs in height categories 1 and 3 (0 to 0.5 m and >1 to 2 m, respectively) were also associated with 4 of the 7 species of small mammals, the canyon mouse, deer mouse, Colorado chipmunk, and least chipmunk. Within these categories, mountain mahogany and Gambel oak covered between 3.3% to 8.3% of the area where these species were present. In summary, open and rocky areas along with deciduous shrub cover up to 2 m high within

pinyon-juniper stands are positively associated with most of the prey species in this vegetation type.

Of the 4 predominant prey species consumed by owls in this area, 3 species, the deer mouse, canyon mouse, and brush mouse were represented in the mixed-conifer vegetation type. Two of these species (deer and brush mouse) were negatively associated with evergreen trees between the >5 to 30 m height categories, whereas the canyon mouse was positively associated with evergreen shrubs between 0 and 1 m in height.

In the mixed-mountain brush vegetation type, 3 of the 4 predominant prey species were associated with somewhat similar vegetative characteristics. Both the brush mouse and the canyon mouse are negatively associated with grass and/or forb cover, while the Mexican woodrat and canyon mouse are positively associated with shrub cover between 0 and 2 m in height.

Within the riparian vegetation type, neither the deer mouse nor the canyon mouse shared any vegetative characteristics, therefore, management of this area would need to be at the species level.

On the mesas, only the deer mouse was found in all three vegetation types. Because this species is a generalist, vegetative characteristics varied within each vegetation type on the mesas. The brush mouse was the only other predominant prey species analyzed on the mesas and it was only captured

in the grass-forb/shrub vegetation type. Within this vegetation type, it was positively associated with grass cover.

Prey Species and Mexican Spotted Owls

Ward and Block (1995) found that the deer mouse, brush mouse, and Mexican woodrat are consumed regularly by Mexican spotted owls throughout most of its range, and that in Utah canyon mice are also likely to be consumed. In our study, the canyon and brush mouse were captured primarily within the canyons, and the woodrats were captured only in the canyons. As mentioned earlier, the Mexican spotted owls studied in this area were primarily (>75%) located within the canyons. Willey (unpubl. data) found that the owls within the canyons sampled were primarily foraging in the pinyon-juniper vegetation type. This correlates with the abundance of its primary prey species, the woodrat, which was predominantly captured in the pinyon-juniper vegetation type. The other prey species of the owl were also abundant in this vegetation type.

Management Implications

Our study showed that the 4 main prey species of the Mexican spotted owl (i.e., deer mouse, canyon mouse, brush mouse, and Mexican woodrat), were found primarily in the pinyon-juniper vegetation type within the canyons. These prey species are also fairly abundant in the other vegetation

types within the canyons. Maintaining the current mixture of vegetation types within the canyons may provide a buffer against the effects of small mammal cycles in any particular vegetation type (Ward and Block 1995). For example, small mammal populations are known to fluctuate around seed and/or cone-crop production (Koehler and Anderson 1991). If a certain tree species produces cones one year, small mammal species that are not extreme habitat specialist (as most of the owls primary prey species are not) may temporarily move into the food abundant areas, thus maintaining viable populations.

In regards to the owls fourth-order selection (Johnson 1980), we recommend that current management practices at the macro-scale be maintained within the canyons. The Monticello Ranger District does not practice timber harvesting in the canyons and only allows cattle grazing on alternate years (J. Forrest, U.S. Forest Service, pers. commun.). We base this recommondation on our results along with D. W. Willey's (unpubl. data) observations of Mexican spotted owls foraging behavior.

At the micro-scale level, we found that rock cover and open, areas among deciduous shrubs between 0 and 2 m high within the pinyon-juniper vegetation type, along with the other variables in each of the prey species models, described the presence of 3 of the 4 predominant prey species of the

owls during our study. It is very difficult to manage at this scale. However, these models can give managers a better understanding of the small mammals' associations within specific areas. If environmental factors in subsequent years are similar to those we experienced during our 2 year study, managers could use our models as starting points if small mammal abundances decrease by seeing which vegetative characteristics were associated with a higher abundance or with the presence of each species.

Skupski (1995) comments, however, on the drawbacks of short-term studies (2 or 3 years) in that they are unlikely to reflect the variation in population dynamics that is found in response to normal ranges of environmental variation. In this light, our study may be revealing only a small part of the natural fluctuations that may occur within these areas. Because prey abundance has been correlated with the reproductive success of owls, a better understanding of small mammal fluctuations within the canyons may be an assest to management of the owls. If managers have some idea of these fluctuations, they may be able to adequately evaluate an area's ability to support owls.

Currently, no timber harvest occurs in the canyons within our study area. As mentioned earlier, however, cattle grazing occurs in alternate years. Ward and Block (1995) cited studies comparing grazed and non-grazed areas,

primarily within meadows and riparian areas. In general, grazed areas had increased deer mouse populations and decreased species diversity. Grandison (1994) suggested that livestock grazing would not affect woodrat numbers due to their xeric habitats. However, within the canyons in the Manti-LaSal National Forest, woodrats also used vegetation types that were not xeric. Therefore, livestock grazing may have a negative effect on woodrat numbers. Future studies within the Manti-LaSal Forest should study the effect of grazing on the abundance of small mammals within the canyons.

In conclusion, the correlation between woodrats and Mexican spotted owls is interesting. This suggests that the pinyon-juniper vegetation type is an important component of the owls home range during the summer and fall seasons based on owl foraging behavior studies, owl diet, and prey abundance of key species. Future research might address this further by assesing whether the amount of pinyon-juniper vegetation type within the home range of individual owl pairs influences owl survival and reproductive success. Until then, maintaining the current management practices within the canyons may assist in the recovery and conservation of Mexican spotted owls in the Manti-LaSal National Forest.

LITERATURE CITED

Armstrong, D. M. 1979. Ecological distribution of rodents in Canyonlands National Park, Utah. Great Basin Nat.

39:199-205.

Bair, F. E. 1992. Weather of U. S. Cities. Gale Research Inc., Detroit, Mich. 1080pp.

Barnes, F. A. 1978. Canyon country Geology. Wasatch Publ. Inc., Salt Lake City, Ut. 160pp.

Barrows, C. W. 1981. Roost selection by spotted owls: an adaptation to heat stress. Condor. 83:302-309.

Best, T. L., S. L. Burt, and J. L. Bartig. 1994. Tamias quadrivittatus. Mammal. Species 466:1-7.

Bonham, C. D. 1989. Measurements for terrestrial vegetation. John Wiley & Sons Inc., New York, N.Y. 338pp.

Burt, W. H., and R. P. Grossenheider. 1976. Peterson field guides. Mammals. Houghton Mifflin Co., Boston, Mass. 289pp.

Carey, A. B. 1985. A summary of the scientific basis for spotted owl management. Pages 50-54 in R. J. Gutierrez, and A. B. Carey, eds. Ecology and management of the spotted owl in the Pacific Northwest. USDA For. Serv. Gen. Tech. Rep. PNW-185. 118pp.

Cornely, J. E., and R. J. Baker. 1986. Neotoma mexicana. Mammal. Species 262:1-7.

Craighead, J. J. and F. C. Craighead. 1956. Hawwks, owls, and wildlife. Stackpole, Harrisburg, Penn. 443pp.

Davis, D. E. 1982. CRC handbook of census methods for

terrestrial vertebrates. CRC Press, Boca Raton, Fla. 397pp.

Dillon, W. R., and M. Goldstein. 1984. Multivariate analysis, methods and applications. John Wiley & Sons, New York, N.Y. 587pp.

Dueser, R. D., and H. H. Shugart, Jr. 1978. Microhabitats in a forest-floor small mammal fauna. Ecology 59:89-98.

Fitzgerald, J. P., C. A. Meaney, and D. M. Armstrong. 1994. Mammals of Colorado. Univ. Press Colo., Denver. 467pp.

Forsman, E. K., E. C. Meslow, and H. M. Wight. 1984. Distribution and biology of the spotted owl in Oregon. Wildl. Monogr. 87:1-64.

Ganey, J. L. , J. A. Johnson, R. P. Balda, and R. W. Skaggs. 1988. Mexican Spotted Owl. Pages 145-150 in R. L. Glinski et al., eds. Proc. Southwest Raptor Manage. Symp. and Workshop. Natl. Wildl. Fed. Sci. and Tech. Ser. 11. Washington, D. C.

-----. 1994. Habitat selection by Mexican spotted owls in northern Arizona. Auk 111:162-169.

Grandison, K. 1994. Programmatic biological assessment of the effects of grazing on the Mexican spotted owl for region 4 southern Utah forests: Dixie, Fishlake, and Manti-LaSal National Forests. U.S. For. Serv., Dixie Nat. For., Cedar City, Ut. 12pp.

Hoffmeister, D. F. 1986. Mammals of Arizona. Univ. of

Arizona Press, Tucson, Ariz. 602pp.

Hosmer, D. W., Jr., and S. Lemeshow. 1989. Applied logistic regression. John Wiley & Sons, New York, N.Y. 307pp.

James, F. C., and H. H. Shugart, Jr. 1970. A Quantitative Method of Habitat Description. Audubon Field Notes 24(6):727-736.

Johnsgaard, P. A. 1988. North American owls: biology and natural history. Smithsonian Inst. Press, Washingtion, D.C. 295pp.

Johnson, D. H. 1981. The use and misuse of statistics in wildlife habitat studies. Pages 11-19 _in_ D. E. Capen, ed. The use of multivariate statistics in studies of wildlife habitat. USDA For. Ser. Gen. Tech. Rep. RM-87.

Johnson, D. W. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Johnson, D. W., and D. M. Armstrong. 1987. _Peromyscus crinitus_. Mammal. species.

Kelt, D. A., P. L. Meserve, and B. K. Lang. 1994. Quantitative habitat associations of small mammals in a temperate rainforest in southern Chile: Empirical patterns and the importance of ecological scale. J. Mammal. 75:890-904.

Kertell, K. 1977. The spotted owl at Zion National Park, Utah. West. Birds 8:147-150.

Koehler, D. K., and F. J. Rohlf. 1981. Habitat use and food selection of small mammals near a sagebrush-crested wheatgrass interface in southeastern Idaho. Great Basin Nat. 51:249-255.

Korpimäki, E., and K. Norrdahl. 1991. Numerical and functional responses of kestrels, short-eared owls, and long-eared owls to vole densities. Ecology 72:814-826.

Krebs, C. J. 1985. Ecology: The experimental analysis of distribution and abundance. Harper & Row, Publ., New York, N.Y. 800pp.

Lechleitner R. R. 1969. Wild mammals of Colorado: their appearance, habits, distribution, and abundance. Pruett Publ. Co., Colo. 254pp.

Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, S.D. 399pp.

Mills, J. N., B. A. Ellis, K. T. McKee, J. I. Maiztegui, and J. E. Childs. 1991. Habitat associations and relative densities of rodent populations in cultivated areas of central Argentina. J. Mammal. 72:470-479.

Morrison, M. L., B. G. Marcot, and R. W. Mannan. 1992. Wildlife-habitat relationships. Univ. Wisconsin Press, Madison. 343pp.

O'Farrell, M. J. 1974. Seasonal activity patterns of rodents in a sagebrush community. J. Mammal. 55(4):809-823.

Reynolds, R. T., R. T. Graham, M. H. Reiser, R. L. Bassett, P. L. Kennedy, D. A. Boyce Jr., G. Goodwin, R. Smith, and E. L. Fisher. 1992. Management recommendations for the northern goshawk in the southwestern United States. Gen. Tech. Rep. RM-217. Ft. Collins, Colo. 90pp.

Rosenzweig, M. L., and J. Winakur. 1969. Population ecology of desert rodent communities: Habitats and environmental complexity. Ecology 60:558-572.

Sakai, H. F., and B. R. Noon. 1993. Dusky-footed woodrat abundance in different-aged forests in northwestern California. J. Wildl. Manage. 57(2):373-382.

Skupski, M. P. 1995. Population ecology of the western harvest mouse, Reithrodontomys megalotis: a long-term perspective. J. Mammal. 76:358-367.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry. Second ed. W. H. Freeman and Co., New York, N.Y. 859pp.

Southern, H. N. 1970. The natural control of a population of Tawny owls (Strix aluco). J. Zool. 162:197-285.

Thornbury, W. D. 1965. Regional Geomorphology of the United States. John Wiley and Sons, Inc., New York, N.Y. 609pp.

Travers, S. E., D. W. Kaufman, and G. A. Kaufman. 1988. Differential use of experimental habitat patches by foraging Peromyscus maniculatus on dark and bright nights. J. Mammal. 69(4):869-872.

USDI Fish and Wildlife Service. 1995. Recovery plan for the Mexican spotted owl. Vol. I. Albuquerque, N.M. 172pp.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Ecology 47:893-901.

Verner, J., M. L. Morrison, and C. J. Ralph. 1986. Wildlife 2000: modeling habitats of terrestrial vertebrates. Univ. Wisconsin Press, Madison. 470pp.

Wagner, P. W., C. D. Marti, and T. C. Boner. 1982. Food of the spotted owl in Utah. Raptor Res. 16:27-28.

Ward, J. P., Jr., and W. M. Block. 1995. Pages 1-48 _in_ USDI Fish and Wildl. Serv. Mexican Spotted Owl Recovery Plan. Vol. II.

Wendland, V. 1984. The influence of prey fluctuations on the breeding success of the Tawny owl (_Strix aluco_). Ibis 126:285-295.

Willy, A. G. 1992. The Habitat Associations of the Dusky-Footed Woodrat (_Neotoma fuscipes_) in Marin County, CA. M.S. Thesis, Univ. Calif. Berkeley. 66pp.

Wilson, D. E. 1968. Ecological distribution of the genus _Peromyscus_. Southwest. Nat. 13:267-274.

Zar, J. H. 1984. Biostatistical Analysis. Second ed. Prentice Hall, Englewood Cliffs, N.J. 718pp.

Zwank, P. J., K. W. Kroel, D. M. Levin, G. M. Southward, and R. C. Romme. 1994. Habitat characteristics of Mexican spotted owls in southwestern New Mexico. J. Field Ornithol. 65:324-334.

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APPENDIX 1. Items recorded along line intercept and foliage height categories used in vegetation sampling in the Manti La-Sal National Forest, San Juan Co., Utah, 1994-1995.

Items:

- -bareground
- -litter=detached forbs and grasses; leaves, cones, and twigs <1 cm diameter
- -gravel
- -small rock (≥1 cm-10 cm)
- -medium rock (>10 cm-50 cm)
- -large rock (>50 cm)
- -boulder (rock outcrop, immovable)
- -water=creek, pond, seep, wet meadow
- -moss
- -lichen (not in trees)
- -small log (1m X ≥15 cm-30 cm)
- -medium log (1m X >30 cm-60cm)
- -large log (1m X >60 cm)
- -stump=tree species ≥5 cm dbh and <3 m tall
- -tree species=≥5 cm dbh
- -shrub=tree species <5 cm dbh and ≥1/4 m tall (<1/4 m tall=tree seedling)
  =shrub species ≥0.5 m diameter

Appendix 1. Continued.

-tree seedling=<5 cm dbh, no dbh, <1/4 m tall

-forb species (alive or dead, but attached)

-grass species (alive or dead, but attached)

<u>Foliage height categories</u>:

1=0.0-0.5 m

2=>0.5-1.0 m

3=>1-2 m

4=>2-5 m

5=>5-15 m

6=>15-30 m

7=>30 m

APPENDIX 2. Descriptions and sampling methods for variables to be used in measuring each plot in the Manti La-Sal National Forest, San Juan Co., Utah, 1994-1995.

Variables	Methods
Habitat Structure	
Percent canopy cover[a]	Percentage of points with woody vegetation $\geq$5 cm dbh; ocular tube (James and Shugart 1970).
Vertical structure[a]	Live foliage and limb heights of each species; estimate heights into foliage height categories (see Appendix 1).
Litter depth	Measure to mm at each meter mark; tape measure.
All items[a]	Identify items (see Appendix 1) at each meter mark.
Environmental Data	
UTM	UTM coordinates; topography map.
Slope	Degrees; compass.
Aspect	Degrees; compass.
Elevation	Meters; topography map.

Appendix 2. Continued.

Slope position	Slope location of plot relative to top and bottom of slope; estimate, 0.0 (bottom) to 1.0 (ridge of hill).
Vegetation strata	Number of distinct vegetation strata within the plot, considered a layer if strata covers >33% of plot area; estimate presence (1) or absence (0).
Vegetation type	Visual estimate of dominant plants.
Vegetation change	Nearest major break in vegetation; visual or maps.
Distance to vegetation change.	Distance in meters; pace or map.
Water type	Nearest water type.
Distance to water type.	Distance in meters; pace or map.
Ephemeral water	Nearest ephemeral water.
Distance to ephemeral water.	Distance in meters; pace or map.
Rock outcrop	Nearest rock outcrop (boulder or

Appendix 2. Continued.

	cliff).
Distance to nearest rock outcrop.	Distance in meters; pace or map.
Dirt road	Distance to nearest dirt road.
Distance to nearest in-service dirt road.	Distance in meters; pace or map.

[a]sample on line intercept

Appendix 3. Relative abundance of each small mammal species within each vegetation type, within each area, by years, seasons, and overall, Manti-LaSal National Forest, San Juan Co., Utah, 1995.

Year-Season Area Vegetation type Species	N	X	SD
1994-Summer			
Mesas			
Peromyscus maniculatus	256	8.7	5.2
P. boylei	2	0.5	0
P. crinitus	1	0.5	---
P. truei	1	0.5	---
Microtus montanus	10	1.0	0.7
Tamias minimus	49	3.1	2.8
Perognathus flavus	4	2.0	---
Canyons			
P. maniculatus	224	5.7	2.4
P. boylei	4	1.1	0.8
P. crinitus	88	3.2	2.3
P. truei	17	1.5	1.6

Appendix 3. Continued.

Neotoma mexicana	7	1.8	1.1
N. albigula	2	0.5	0
N. sp.	1	0.5	---
T. minimus	5	2.5	---
T. quadrivittatus	10	1.0	0.5
Citellus variegatus	1	0.5	---
1994-Fall			
Mesas			
P. maniculatus	178	7.0	6.6
P. boylei	1	0.5	---
M. montanus	26	1.7	1.9
T. minimus	25	1.6	0.9
C. variegatus	1	0.5	---
P. flavus	2	1.0	---
Reithrodontomys megalotis	9	4.6	---
Dipodomys ordii	3	1.5	---
Sorex sp.	3	0.8	0.4
Canyons			
P. maniculatus	278	7.9	5.9
P. boylei	52	2.0	1.4
P. crinitus	145	5.0	4.0
P. truei	12	0.9	0.4

Appendix 3. Continued.

N. mexicana	26	1.0	0.7
N. albigula	1	0.5	---
N. cinerea	2	0.6	0.1
N. sp.	1	0.5	---
M. montanus	4	0.7	0.3
T. minimus	8	0.8	0.4
T. quadrivittatus	12	1.6	1.0
C. variegatus	1	0.5	---
1995-Summer			
Mesas			
P. maniculatus	186	7.9	4.4
P. boylei	11	5.6	---
P. truei	4	1.0	0.7
M. montanus	33	2.1	1.0
T. minimus	66	3.0	1.9
Sorex sp.	1	0.5	---
Canyons			
P. maniculatus	171	4.6	2.8
P. boylei	91	3.6	2.3
P. crinitus	38	3.5	2.2
P. truei	14	1.4	1.2
N. mexicana	10	0.6	0.3

Appendix 3. Continued.

N. albigula	2	0.5	0
N. cinerea	1	0.5	---
M. montanus	1	0.5	---
T. minimus	24	1.4	1.1
T. quadrivittatus	17	1.8	1.5
C. variegatus	8	0.7	0.3
1995-Fall			
Mesas			
P. maniculatus	230	13.0	6.4
P. boylei	6	1.0	0.5
P. crinitus	1	0.5	---
P. truei	2	0.5	0
M. montanus	24	2.4	2.4
T. minimus	65	3.7	3.3
Canyons			
P. maniculatus	233	6.8	4.3
P. boylei	68	2.4	1.6
P. truei	27	3.5	2.0
C. variegatus	2	0.5	0
1994-Summer			
Mesas			
Aspen			

Appendix 3. Continued.

P. maniculatus	61	6.3	4.3
P. crinitus	1	0.5	---
M. montanus	8	1.4	0.7
T. minimus	7	1.8	1.8
N. mexicana	3	0.8	0.4
N. albigula	3	0.8	0.4
M. montanus	5	0.5	0
T. minimus	50	2.4	1.8
T. quadrivittatus	14	1.2	1.1
Ponderosa pine			
P. maniculatus	60	6.1	3.1
P. boylei	1	0.5	---
T. minimus	4	1.0	0.7
Grass-forb/shrub			
P. maniculatus	135	13.7	4.3
P. boylei	1	0.5	---
P. truei	1	0.5	---
M. montanus	2	0.5	0
T. minimus	38	4.9	2.9
P. flavus	4	2.0	---
Canyons			
Mixed-conifer			

Appendix 3. Continued.

P. maniculatus	48	4.8	2.4
P. crinitus	17	4.4	1.3
P. truei	1	0.5	---
T. quadrivittatus	3	0.8	0.4
Pinyon-juniper			
P. maniculatus	54	5.5	1.5
P. boylei	3	1.6	---
P. crinitus	31	3.9	2.8
P. truei	13	1.9	1.8
N. mexicana	5	2.5	---
N. albigula	2	0.5	0
N. sp.	1	0.5	---
T. quadrivittatus	6	1.5	0
C. variegatus	2	0.5	0
Mixed-mountain brush			
P. maniculatus	61	6.2	3.2
P. boylei	1	0.5	---
P. crinitus	25	3.2	2.9
P. truei	1	0.5	---
N. mexicana	2	1.0	---
T. minimus	5	2.5	---
T. quadrivittatus	1	0.5	---

Appendix 3. Continued.

Riparian			
P. maniculatus	61	6.1	2.8
P. crinitus	15	1.9	1.4
P. truei	2	1.0	---
C. variegatus	1	0.5	---
1994-Fall			
Mesas			
Aspen			
P. maniculatus	26	3.4	2.7
M. montanus	19	2.5	2.5
T. minimus	5	2.5	---
C. variegatus	1	0.5	---
Sorex sp.	3	0.8	0.4
Ponderosa pine			
P. maniculatus	25	3.2	2.4
T. minimus	9	1.5	1.4
T. quadrivittatus	1	0.5	---
Grass-forb/shrub			
P. maniculatus	127	13.0	7.1
P. boylei	1	0.5	---
M. montanus	7	0.8	0.4
T. minimus	5	2.5	---

Appendix 3. Continued.

P. flavus	2	1.0	---
R. megalotis	9	4.6	---
D. ordii	3	1.5	---
Canyons			
Mixed-conifer			
P. maniculatus	76	7.7	3.6
P. boylei	6	1.5	0
P. crinitus	16	4.1	0
N. mexicana	2	0.5	0
M. montanus	1	0.5	---
T. minimus	2	1.0	---
Pinyon-juniper			
P. maniculatus	14	2.5	0.6
P. boylei	20	2.2	1.0
P. crinitus	59	6.3	5.8
P. truei	9	0.9	0.4
N. mexicana	12	1.6	0.8
N. cinerea	2	0.6	0.1
N. sp.	1	0.5	---
T. minimus	1	0.5	---
T. quadrivittatus	9	2.4	0.4
C. variegatus	1	0.5	---

Appendix 3. Continued.

Mixed-mountain brush			
P. maniculatus	94	9.7	7.7
P. boylei	22	2.3	1.4
P. crinitus	41	5.2	4.0
P. truei	1	0.5	---
N. mexicana	4	0.7	0.3
T. minimus	4	0.8	0.6
T. quadrivittatus	1	0.5	---
Riparian			
P. maniculatus	94	9.6	6.7
P. boylei	4	1.0	0.7
P. crinitus	28	3.6	3.2
P. truei	2	1.0	---
N. mexicana	8	1.0	0.8
N. albigula	1	0.5	---
M. montanus	3	0.8	0.4
T. minimus	1	0.5	---
T. quadrivittatus	2	1.0	---
1995-Summer			
Mesas			
Aspen			
P. maniculatus	51	6.4	4.2

Appendix 3. Continued.

M. montanus	17	2.2	0.5
T. minimus	24	4.8	2.9
Sorex sp.	1	0.5	---
Ponderosa pine			
P. maniculatus	47	5.9	4.7
P. truei	1	0.5	---
M. montanus	3	0.8	0.4
T. minimus	18	2.3	1.3
Grass-forb/shrub			
P. maniculatus	88	11.3	4.1
P. boylei	11	5.6	---
P. truei	3	1.5	---
M. montanus	13	3.3	0.4
T. minimus	23	2.9	1.6
Canyons			
Mixed-conifer			
P. maniculatus	31	3.2	2.1
P. boylei	19	2.5	1.5
P. crinitus	11	5.7	---
N. mexicana	2	0.5	0
T. minimus	5	1.3	1.1
T. quadrivittatus	8	2.1	2.3

Appendix 3. Continued.

C. variegatus	2	0.5	---
Pinyon-juniper			
P. maniculatus	35	4.5	2.0
P. boylei	38	4.9	3.3
P. crinitus	6	1.6	0.8
P. truei	12	1.5	1.3
N. mexicana	3	0.8	0.4
N. albigula	1	0.5	---
N. cinerea	1	0.5	---
T. minimus	3	0.8	0.4
T. quadrivittatus	6	3.1	---
C. variegatus	2	0.5	0
Mixed-mountain brush			
P. maniculatus	32	5.5	3.6
P. boylei	11	2.8	2.5
P. crinitus	10	5.1	---
N. mexicana	3	0.8	0.4
M. montanus	1	0.5	---
T. minimus	4	2.1	---
T. quadrivittatus	1	0.5	---
C. variegatus	2	1.0	---
Riparian			

Appendix 3. Continued.

P. maniculatus	25	4.4	3.5
P. boylei	23	4.0	0.6
P. crinitus	11	5.1	---
N. mexicana	1	0.5	---
T. minimus	7	3.7	---
T. quadrivittatus	1	0.5	---
C. variegatus	2	1.0	---
Grass-forb/shrub			
P. maniculatus	23	11.6	---
T. minimus	2	1.0	---
Ponderosa-shrub			
P. maniculatus	8	4.1	---
P. truei	2	1.0	---
Ponderosa-rock			
P. maniculatus	9	4.7	---
N. mexicana	1	0.5	---
N. albigula	1	0.5	---
T. minimus	2	1.0	---
Ponderosa-oak			
P. maniculatus	8	4.0	---
1995-Fall			
Mesas			

Appendix 3. Continued.

Aspen			
P. maniculatus	63	10.6	1.4
P. boylei	2	1.0	---
M. montanus	20	2.4	2.8
T. minimus	11	1.9	1.2
Ponderosa pine			
P. maniculatus	55	9.3	1.7
P. crinitus	1	0.5	---
P. truei	2	0.5	0
M. montanus	1	0.5	---
T. minimus	26	4.4	5.2
Grass-forb/shrub			
P. maniculatus	112	19.0	8.7
P. boylei	4	1.0	0.7
M. montanus	3	1.5	---
T. minimus	28	4.8	2.6
Canyons			
Mixed-conifer			
P. maniculatus	39	4.9	3.4
P. boylei	8	1.3	0.3
P. truei	4	2.0	---
M. montanus	1	0.5	---

Appendix 3. Continued.

T. minimus	9	2.5	0.5
T. quadrivittatus	1	0.5	---
Pinyon-juniper			
P. maniculatus	42	5.5	3.6
P. boylei	23	4.0	2.1
P. truei	23	4.0	1.6
N. mexicana	2	1.0	---
M. montanus	1	0.5	---
T. minimus	10	2.6	2.3
T. quadrivittatus	7	1.2	1.3
Mixed-mountain brush			
P. maniculatus	34	6.8	3.2
P. boylei	14	2.4	1.6
M. montanus	1	0.5	---
T. minimus	2	0.5	0
T. quadrivittatus	1	0.5	---
Riparian			
P. maniculatus	23	3.9	1.3
P. boylei	20	2.4	1.6
N. mexicana	1	0.5	---
M. montanus	1	0.5	---
T. minimus	4	1.0	0.7

Appendix 3. Continued.

T. quadrivittatus	5	2.6	---
Grass-forb/shrub			
P. maniculatus	36	18.3	---
T. minimus	4	2.0	---
Ponderosa-shrub			
P. maniculatus	20	10.1	---
P. boylei	2	1.0	---
T. minimus	12	6.1	---
Ponderosa-rock			
P. maniculatus	22	11.7	---
T. minimus	10	5.3	---
Ponderosa-oak			
P. maniculatus	17	8.5	---
P. boylei	1	0.5	---
M. montanus	1	0.5	---
T. minimus	4	2.0	---
C. variegatus	1	0.5	---
1994			
Mesas			
P. maniculatus	434	7.6	4.6
P. boylei	3	0.5	0
P. crinitus	1	0.5	---

Appendix 3. Continued.

P. truei	1	0.5	---
M. montanus	36	1.3	0.9
T. minimus	73	2.1	1.5
T. quadrivittatus	1	0.5	---
C. variegatus	1	0.5	---
P. flavus	6	1.5	0.7
R. megalotis	9	4.6	---
D. ordii	3	1.5	---
Sorex sp.	3	0.8	0.4
Canyons			
P. maniculatus	502	6.5	2.4
P. boylei	55	1.5	0.7
P. crinitus	232	4.1	1.3
P. truei	19	0.8	0.3
N. mexicana	32	1.2	0.7
N. albigula	3	0.5	0
N. cinerea	2	0.6	0.1
N. sp.	2	0.5	0
M. montanus	4	0.7	0.2
T. minimus	10	0.7	0.2
T. quadrivittatus	22	1.5	0.8
C. variegatus	5	0.5	0

Appendix 3. Continued.

1995			
Mesas			
P. maniculatus	424	10.4	4.7
P. boylei	17	2.5	2.7
P. crinitus	1	0.5	---
P. truei	5	1.0	0.7
M. montanus	57	1.8	1.1
T. minimus	130	3.5	1.3
Sorex sp.	1	0.5	---
Canyons			
P. maniculatus	404	7.0	4.1
P. boylei	159	2.7	1.4
P. crinitus	38	4.5	2.0
P. truei	41	2.1	1.3
N. mexicana	13	0.7	0.2
N. albigula	5	0.7	0.3
N. cinerea	1	0.5	---
M. montanus	6	0.5	0
T. minimus	78	2.3	1.7
T. quadrivittatus	31	1.6	1.3
C. variegatus	10	0.7	0.3
1994			

Appendix 3. Continued.

Mesas			
Aspen			
_P_. _maniculatus_	87	5.0	3.8
_P_. _crinitus_	1	0.5	---
_M_. _montanus_	27	2.0	0.8
_T_. _minimus_	12	2.2	0.6
_C_. _variegatus_	1	0.5	---
Sorex sp.	3	0.8	0.4
Ponderosa pine			
_P_. _maniculatus_	124	4.8	3.1
_P_. _boylei_	1	0.5	---
_T_. _minimus_	13	1.5	1.1
_T_. _quadrivittatus_	1	0.5	---
Grass-forb/shrub			
_P_. _maniculatus_	262	13.4	5.5
_P_. _boylei_	2	0.5	0
_P_. _truei_	1	0.5	---
_M_. _montanus_	9	0.8	0.4
_T_. _minimus_	49	3.2	2.7
_P_. _flavus_	6	1.5	0.7
_R_. _megalotis_	9	4.6	---
_D_. _ordii_	3	1.5	---

Appendix 3. Continued.

Canyons			
Mixed-conifer			
P. maniculatus	124	6.3	3.2
P. boylei	6	1.5	0
P. crinitus	33	4.2	2.7
P. truei	1	0.5	---
N. mexicana	2	0.5	0
M. montanus	1	0.5	---
T. minimus	2	1.0	---
T. quadrivittatus	3	0.8	0.4
C. variegatus	1	0.5	---
Pinyon-juniper			
P. maniculatus	68	4.4	2.0
P. boylei	23	2.1	1.7
P. crinitus	90	5.2	4.6
P. truei	16	1.4	1.4
N. mexicana	17	1.8	0.8
N. albigula	2	0.5	0
N. cinerea	2	0.6	0.1
N. sp.	2	0.5	0
T. minimus	1	0.5	---
T. quadrivittatus	15	1.9	0.5

Appendix 3. Continued.

C. variegatus	3	0.5	0
Mixed-mountain brush			
P. maniculatus	155	7.9	5.9
P. boylei	23	2.0	1.4
P. crinitus	66	4.2	3.4
P. truei	2	0.5	0
N. mexicana	6	0.8	0.3
T. minimus	9	1.5	1.0
T. quadrivittatus	2	0.5	0
Riparian			
P. maniculatus	155	7.9	5.2
P. boylei	4	1.0	0.7
P. crinitus	43	2.7	2.5
P. truei	4	1.0	0
N. mexicana	8	1.0	0.8
N. albigula	1	0.5	---
M. montanus	3	0.8	0.4
T. minimus	1	0.5	---
T. quadrivittatus	2	1.0	---
1995			
Mesas			
Aspen			

Appendix 3. Continued.

P. maniculatus	144	8.3	3.4
P. boylei	2	1.0	---
M. montanus	33	2.7	1.8
T. minimus	35	2.9	2.4
Ponderosa pine			
P. maniculatus	102	7.4	3.8
P. crinitus	1	0.5	---
P. truei	3	0.5	0
M. montanus	4	0.7	0.3
T. minimus	44	3.2	3.3
Grass-forb/shrub			
P. maniculatus	200	14.6	7.1
P. boylei	15	2.5	2.7
P. truei	3	1.5	---
M. montanus	16	2.7	1.1
T. minimus	51	3.7	2.1
Canyons			
Mixed-conifer			
P. maniculatus	70	4.0	2.7
P. boylei	27	2.0	1.2
P. crinitus	11	5.7	---
P. truei	4	2.0	---

Appendix 3. Continued.

N. mexicana	2	0.5	0
T. minimus	14	1.9	1.0
T. quadrivittatus	7	3.7	---
C. variegatus	2	0.5	0
Pinyon-juniper			
P. maniculatus	77	4.9	2.7
P. boylei	61	4.5	2.7
P. crinitus	6	1.6	0.8
P. truei	35	2.6	1.8
N. mexicana	5	0.8	0.3
N. albigula	3	0.8	0.4
N. cinerea	1	0.5	---
M. montanus	1	0.5	---
T. minimus	13	1.7	1.7
T. quadrivittatus	13	1.7	1.4
C. variegatus	3	0.5	0
Mixed-mountain brush			
P. maniculatus	66	6.1	3.1
P. boylei	25	2.6	1.7
P. crinitus	10	5.1	---
N. mexicana	3	0.8	0.4
M. montanus	2	0.5	0

Appendix 3. Continued.

T. minimus	6	0.9	0.8
T. quadrivittatus	2	0.5	0
Riparian			
P. maniculatus	48	4.2	2.4
P. boylei	43	2.6	1.7
P. crinitus	11	5.6	---
N. mexicana	2	0.5	0
M. montanus	1	0.5	---
T. minimus	11	1.9	1.6
T. quadrivittatus	7	1.8	1.1
C. variegatus	2	1.0	---
Grass-forb/shrub			
P. maniculatus	59	15.0	4.7
T. minimus	6	1.5	0.7
Ponderosa-shrub			
P. maniculatus	28	7.1	4.2
P. boylei	2	1.0	---
P. truei	2	1.0	---
T. minimus	12	6.1	---
Ponderosa-rock			
P. maniculatus	31	8.2	4.9
N. mexicana	1	0.5	---

Appendix 3. Continued.

T. minimus	12	3.2	3.0
Ponderosa-oak			
P. maniculatus	25	6.3	3.2
P. boylei	1	0.5	---
M. montanus	1	0.5	---
T. minimus	4	2.0	---
Overall			
Mesas			
P. maniculatus	858	9.2	2.7
P. boylei	20	1.6	2.2
P. crinitus	2	0.5	0
P. truei	6	0.7	0.3
M. montanus	93	1.8	0.6
T. minimus	203	2.9	0.9
T. quadrivittatus	1	0.5	---
C. variegatus	1	0.5	---
P. flavus	6	1.5	0.7
R. megalotis	9	4.6	---
D. ordii	3	1.5	---
Sorex sp.	4	0.7	0.2
Canyons			
P. maniculatus	906	6.3	1.4

Appendix 3. Continued.

P. boylei	215	2.3	1.0
P. crinitus	271	2.3	1.0
P. truei	70	1.8	1.1
N. mexicana	46	1.2	0.5
N. albigula	8	0.6	0.2
N. cinerea	3	0.6	0.1
N. sp.	2	0.5	0
M. montanus	10	0.6	0.1
T. minimus	87	1.8	0.8
T. quadrivittatus	53	1.6	1.1
C. variegatus	15	0.5	0.1
Overall			
Mesas			
Aspen			
P. maniculatus	201	6.7	3.0
P. boylei	2	1.0	---
P. crinitus	1	0.5	---
M. montanus	64	2.1	0.5
T. minimus	47	2.8	1.4
C. variegatus	1	0.5	---
Sorex sp.	3	0.8	0.4
Ponderosa pine			

Appendix 3. Continued.

P. maniculatus	187	6.1	2.5
P. boylei	2	1.0	---
P. crinitus	1	0.5	---
P. truei	3	0.5	0
M. montanus	4	0.7	0.3
T. minimus	57	2.3	1.4
T. quadrivittatus	1	0.5	---
Grass-forb/shrub			
P. maniculatus	462	14.2	3.2
P. boylei	17	1.9	2.4
P. truei	4	1.0	0.7
M. montanus	25	1.5	1.2
T. minimus	100	3.5	1.7
P. flavus	6	1.5	---
R. megalotis	9	4.6	---
D. ordii	3	1.5	---
Canyons			
Mixed-conifer			
P. maniculatus	194	5.2	1.9
P. boylei	33	1.8	0.8
P. crinitus	44	4.7	1.0
P. truei	5	1.3	1.1

Appendix 3. Continued.

N. mexicana	4	0.5	0
M. montanus	2	0.5	0
T. minimus	16	1.6	0.7
T. quadrivittatus	12	1.0	0.8
C. variegatus	3	0.5	0
Pinyon-juniper			
P. maniculatus	145	4.6	2.3
P. boylei	84	3.4	2.5
P. crinitus	96	4.6	4.4
P. truei	57	1.7	1.4
N. mexicana	22	1.4	0.7
N. albigula	5	0.5	0
N. cinerea	3	0.5	0.1
N. sp.	2	0.5	0
M. montanus	1	0.5	---
T. minimus	14	0.8	0.3
T. quadrivittatus	28	1.8	0.8
C. variegatus	6	0.5	0
Mixed-mountain brush			
P. maniculatus	221	7.3	5.0
P. boylei	48	2.2	1.5
P. crinitus	76	4.3	3.2

Appendix 3. Continued.

P. truei	2	0.5	0
N. mexicana	11	0.8	0.3
M. montanus	2	0.5	0
T. minimus	12	1.2	0.9
T. quadrivittatus	4	0.5	0
Riparian			
P. maniculatus	203	6.5	4.6
P. boylei	47	3.0	1.4
P. crinitus	54	3.1	2.5
P. truei	4	1.0	0
N. mexicana	10	0.8	0.6
N. albigula	1	0.5	---
M. montanus	4	0.7	0.3
T. minimus	9	1.6	1.5
T. quadrivittatus	9	1.5	0.9
C. variegatus	2	1.0	---
Grass-forb/shrub			
P. maniculatus	59	15.0	4.7
T. minimus	6	1.5	0.7
Ponderosa-shrub			
P. maniculatus	28	7.1	4.2
P. boylei	2	1.0	---

Appendix 3. Continued.

P. truei	2	1.0	---
T. minimus	12	6.1	---
Ponderosa-rock			
P. maniculatus	31	8.2	4.9
N. mexicana	1	0.5	---
T. minimus	12	3.2	3.0
Ponderosa-oak			
P. maniculatus	25	6.3	3.2
P. boylei	1	0.5	---
M. montanus	1	0.5	---
T. minimus	4	2.0	---
1994			
P. maniculatus	936	7.2	5.1
P. boylei	59	1.6	1.3
P. crinitus	234	4.0	3.4
P. truei	30	1.1	1.1
N. mexicana	33	1.1	0.8
N. albigula	3	0.5	0
N. cinerea	2	0.5	0
N. sp.	2	0.5	0
M. montanus	40	1.3	1.4
T. minimus	87	2.0	1.9

Appendix 3. Continued.

T. quadrivittatus	22	1.1	0.7
C. variegatus	6	0.5	0
P. flavus	6	1.5	0.7
R. megalotis	9	4.6	---
D. ordii	3	1.5	---
Sorex sp.	3	0.8	0.4
1995			
P. maniculatus	820	7.3	5.0
P. boylei	176	2.9	2.0
P. crinitus	39	3.4	2.4
P. truei	47	1.8	1.7
N. mexicana	13	0.7	0.3
N. albigula	5	0.7	0.3
N. cinerea	1	0.5	---
M. montanus	63	2.7	2.1
T. minimus	205	2.6	2.2
T. quadrivittatus	31	1.5	1.3
C. variegatus	10	0.6	0.2
Sorex sp.	1	0.5	---
Overall			
P. maniculatus	1756	7.2	5.0
P. boylei	235	2.4	1.9

Appendix 3. Continued.

P. crinitus	273	4.0	3.2
P. truei	77	1.5	1.4
N. mexicana	46	0.9	0.6
N. albigula	8	0.6	0.2
N. cinerea	3	0.5	0.1
N. sp.	2	0.5	0
M. montanus	103	2.0	1.9
T. minimus	292	2.4	2.1
T. quadrivittatus	53	1.3	1.1
C. variegatus	16	0.5	0.1
P. flavus	6	1.5	0.7
R. megalotis	9	4.6	---
D. ordii	3	1.5	---
Sorex sp.	4	0.7	0.3